ABB Review

The corporate technical journal of the ABB Group

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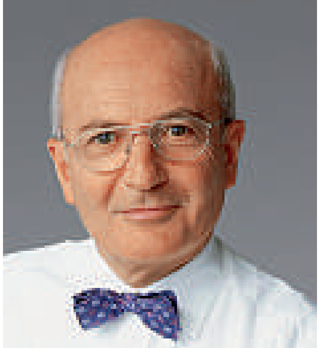
Special Report: Robotics



Intelligent muscles

When in 1974 ABB launched the world's first fully electrical, microprocessor controlled industrial robot it took industrial robotics into a new dimension of speed, accuracy and flexibility. Thirty years later ABB has delivered 115,000 robots worldwide, more than any other supplier. This success story is based on a continuous stream of pioneering innovation in robotics that has not yet come to an end.

Robots have not only become stronger, they can also operate over larger working areas and can position parts with sub-millimeter accuracy. This geometrical positioning ability replaces specialized equipment and greatly simplifies production cell design.

Welding is one of the broad application areas of industrial robots. In order to permit the robot to work with the experience of a professional welder and with the highest accuracy, ABB has developed the Virtual Arc software.

The time consuming and expensive task of robot programming is no issue any more. Robot Studio, another intelligent solution from ABB, allows robots to be programed off-line on a PC.

Often robots also have to perform tasks in coordination. Again, ABB has developed a controller, IRC5, that simultaneously controls up to four robots or positioning devices with a maximum of 36 servo axes. For example, two robots welding simultaneously on the same workpiece, while the positioning devices continuously move the servo axes. Thus, the robots reach every required seam position without interrupting the welding. The improved path accuracy and better repeatability contribute to a higher quality.

The days that robot grippers were not sensitive and could not carry out difficult operations are over. The new ABB robot force control technology shows the way – robots can even assembly gearboxes, up to now only possible for experienced workers.

ABB robots are not only strong but can be very flexible, too. The FlexPicker is a parallel kinematics robot, which offers a great combination of speed and flexibility. Thanks to picking rates exceeding 120 items per minute products such as metal parts, pralines or even pizza can be economically picked and placed.

Building successful robots today is no longer an issue of mechanical design alone. The programming and the understanding of the processes these machines have to perform is the key to success. The latest step towards a better use of robots comes from virtual reality. Combining the visual appearance of an object with the background information of robot handling allows a very easy, forward oriented programming. ABB made the first test with this technology and the researchers involved were nominated as one the world's 100 young innovators by MIT, underlining the innovative spriti underlying ABB's work.

In this Special issue of ABB Review you can learn about this innovative power. We hope you share our enthusiasm about the success of ABB robots.

Markus Bayegan
Chief Technology Officer
ABB Ltd

Committed to manufacturing

Thirty years in Robotics is not a very long time but as this Special Issue of ABB Review reveals, significant progress has been made. The range of innovations and the spectra of applications developed here provide a great overview and insight into how far the industry has come. It is with great pride that I read the articles, which reflect the leading role ABB has held during this brief episode – and still holds. In most cases – and this is equally true for customers, partners and co-workers – only a thin slice of what we are doing is visible at one time, but this report presents a comprehensive review of the current state of affairs.

We, in ABB, have a passion for serving our customers and a conviction that leading – in many cases unparalleled technologies – is required to address the issues and challenges our customer face. This conviction is the very foundation of the efforts resulting in the products, solutions and services you can read about in this issue.

We take pride in working closely with customers and partners when developing new technology for the future. Our record shows that we are good innovators - to be innovative and relentless is not only expected from our engineers and scientists – it is in our lifeblood. Serving discrete manufacturing in its many variations and in a truly global market must be regarded as one of the most competitive businesses there is. This collaboration around R&D is pivotal in securing that tomorrow's products continue to address the needs of our customers every time and all the time – with the right features, at the right cost and the right quality. ABB's 30 years of history in robotics and flexible automation is the proof that we are succeeding.

I find that the business responsibilities of today go beyond the short-term aspects of delivering productivity enhancing solutions. With responsibility for future generations we must be concerned with sustainability and environmental matters. We have macro-economic currents such as the development of countries like China and India. In addition we have big-time changes in consumer patterns such as, for example, the boom in mobile phone usage. It is an intriguing and dynamically changing world.

A core piece of all this is manufacturing. Manufacturing that consumes less energy with less waste, manufacturing that follows market demand into new corners of the world and finally manufacturing of new, usually more compact, versatile and cheaper products.

We are committed to remain at the center of these developing events and are committed to support our customers and partners with technology; packaged into products, services and solutions for flexible manufacturing in a changing world.

I hope you get a flavor of both the breadth and the depth of our expertise. I hope that you contact the author if you find a topic interesting, and I hope that you test us if you have a manufacturing challenge. We are tirelessly working to stay ahead to keep you ahead.
Enjoy!

Bo Elisson
Head of ABB's Business Area Manufacturing Automation

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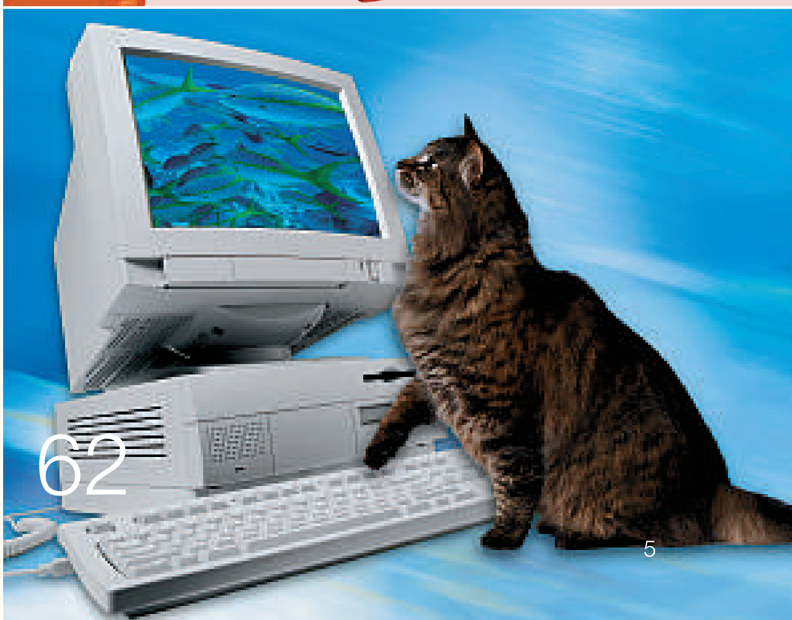


Thirty years in robotics

Brian Rooks

Productivity enhancing robot based applications are omnipresent in discrete manufacturing across the world. The advancement during the last 30 years has been significant. Initially single robots were used for relatively simple and monotonous tasks in hazardous environment. Today multi-robot synchronized configurations are dealing with sophisticated assignments in flexible production cells. ABB has been a prime driver in this rapid development process. The following article highlights the milestones achieved along this exciting journey.

The first industrial robot appeared in 1961 when a Unimate was supplied to General Motors for tending a die casting machine. The Unimate, the brain child of Joseph Engelberger, the “Father of the Industrial Robot”, was hydraulically driven, a technology that dominated the fledgling industrial robot business for its first decade. Then in 1974, the Swedish company ASEA developed the IRB 6, the first all-electric industrial robot. This 6 kg capacity device was unique, not only in the drive system but also in its anthropomorphic configuration and its use of a microprocessor control system. It set new robot standards in the small footprint, the speed of movement and positioning accuracy and gave rise to a number of IRB 6 look-alikes.

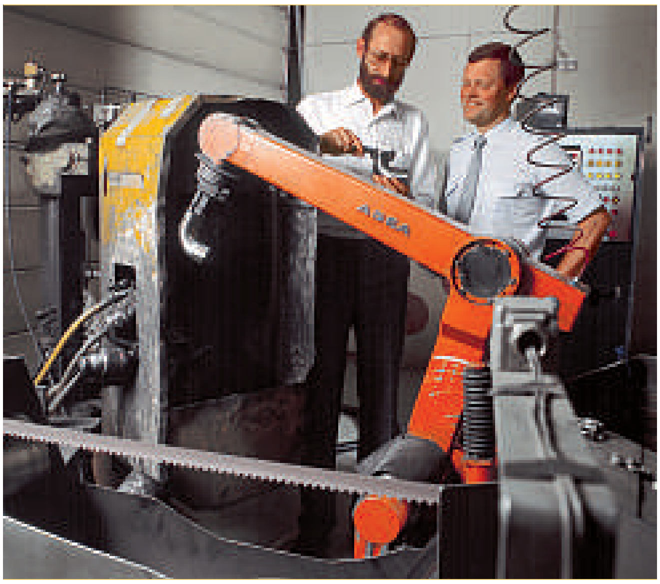
Electric drive robots opened up new applications not possible with hydraulic machines, in particular arc welding. However, the first application outside of ASEA was polishing stainless steel pipe bends for the food industry at Swedish company, Magnusson. Its first IRB 6 was installed in 1974 1, with further units delivered in 1975. These robots ran virtually non-stop in a dirty environment for over 25 years. This factory became one of the first in the world to operate around the clock, seven days a week, completely unmanned.

Spot welding continued to be the domain of the hydraulic robot until 1975 when ASEA launched the IRB 60, similar in design to the IRB 6 but with a 60 kg capacity. The first of these was supplied to Saab in Sweden for spot welding car bodies 2. Perhaps the “final nail in the coffin” of the hydraulic robot spot welder was the IRB 90, launched in 1982, which ASEA designed specifically for spot welding. It was a full 6-axis device with integrated WAC (water, air, current) supplies built into the arm.

Robots for painting

However, still in the era of the hydraulic robot, a significant event took place in Norway, which was later to impact on ASEA’s robot business. Trallfa, a small agricultural engineering company was having difficulty in recruiting labour to paint its wheelbarrows and sought a solution

1 In 1974 Magnusson AB became ASEA's first external robot customer. Manager Leif Jönsson together with Lennart Benz of ASEA monitor the installation.



2 The SAAB Model 99 of 1975 was an early spot welding application.

through automation, a challenge taken up by a young engineer, Ole Molaug. In 1966 he developed the world's first painting robot driven by hydraulics, of which an early version is shown in 3. It differed from the Unimate in that it had continuous path control and programs were created by recording the spray patterns of a skilled painter onto magnetic tape.

Initially, this automatic painter was used solely internally but such was its success that Trallfa decided to market it outside the company. Its first sale of the Trallfa TR-2000 was in 1969 to Swedish company, Gustavsberg for enamelling sanitary wear such as bath tubs and shower trays.

In 1985 Trallfa was acquired by ASEA and soon afterwards development started on an electric drive painting robot, culminating in the release of ABB's first electric drive paint robot, the TR-5000, in 1988 – the year ASEA merged with the Swiss company, Brown Boveri to form ABB. Prior to this development, hydraulic drives were exclusively used for painting robots due to their intrinsic safety. The TR-5000, however, saw intrinsic safety achieved with electric drives and their inherent benefits of speed, accuracy and electronic controls were brought to the painting process.

Evolution of robot mechanics

Such was the elegance of the IRB 6 design that its basic anthropomorphic kinematics with rotary joints movements are continued in today's range of ABB robots. What has changed over the 30 years has been the speed, accuracy and space efficiency with larger working envelopes and more compact footprints.

ABB's first major advance in robot mechanics after the IRB 6 was the 10 kg capacity IRB 2000 launched in 1986 4. In this second generation design, backlash-free gearboxes replaced ballscrew drives for the "hip" and "shoulder" axes, resulting in better spatial kinematics. But, the other significant change was the switch from DC to AC drive motors. AC motors deliver higher torques, are physically smaller than DC motors, are brushless and consequently easier to maintain and have a longer life.

Flexibility and adaptability are features constantly called for by industrial robot users, and in 1991 ABB met these demands head-on with the heavy duty (150 kg capacity) IRB 6000 5. Aimed primarily at spot welding and large component handling, the IRB 6000 was built on a modular concept with a range of base, arm and wrist modules so that it could be optimised for every user's needs. The IRB 6000 was also highly cost competitive through its "lean design" with 60 % fewer parts than the IRB 90. It was ABB's most successful spot welding robot with many large multi-robot orders from leading car manufacturers.

High-speed robots

While the anthropomorphic arm has dominated the scene for the past 30 years there are some high-speed small part assembly and product picking applications where the design is limited and other configurations have emerged.

One of the most successful designs was the SCARA (Selective Compliance Assembly Robot ARM), developed by Professor Hiroshi Makino at Yamanashi University and launched commercially by several Japanese robot manufacturers in 1981. ABB introduced its own SCARA, the IRB 300 in 1987.

In 1984 ABB developed what was believed to be the world's fastest assembly robot, the IRB 1000, which had a

3 Early version of the Trallfa paint robot from 1969.

"pendulum" configuration with the arm suspended from a pivot. The arm's moving masses were concentrated at the pivot, minimising the moments of inertia and resulting in accelerations of 2g within a working envelope much larger than possible with a SCARA.

But even these robots were not fast enough for on-line picking operations in such as the electronics and food industries. To meet such demand ABB introduced the IRB 340 FlexPicker robot in 1998. Based on the Delta robot conceived by Professor Raymond Clavel at EPFL in Switzerland, the FlexPicker is capable of 10g acceleration and 2 picks per second, matching human operators in both speed and versatility when handling small items such as electronic components to chocolates 6.

Advances in control systems

While mainstream robot kinematics has continued on an evolutionary path, the control systems, operator (HMI) interfaces and software have changed beyond all recognition. The control system for the IRB 6 in 1974, later designated the S1 and very advanced for its time, had a single 8-bit Intel 8008 microprocessor, an HMI with a 4-digit LED readout and 12 punch buttons, and rudimentary software for axis interpolation and movement control. It needed specialist knowledge to program and operate.

The first "breakthrough" in set-up and programming came with the S2 introduced in 1981. Based on two Motorola 68000 microprocessors, the S2's HMI or "teach pendant" incorporated a joystick for intuitive jogging and positioning of the robot axes. Also introduced were the concept of the TCP (Tool Centre Point) and a new programming language, ARLA (ASEA Programming Robot Language). These features made programming and set-up easier and quicker for both experienced and untrained robot users.

Other new software for S2 included, limited process software such as arc welding functions and "built-in" weld timers for spot welding, and a kinematic model of the robot arm. The latter enabled the IRB 6000 to gain a level of performance not limited by the physical stiffness of the physical structure, and was ABB's first step along the road to the complete dynamic and kinematic modelling available in today's products.

> The S4 controller was designed to improve two areas of critical importance to the user; the man-machine interface and the robot's technical performance.

The S3 control unit introduced during 1986 differed from the S2 mainly in its switch to AC drives such as for the IRB 2000 series. The next big change came with the S4, launched in 1992 and which many in ABB regarded as big an advance as the introduction of the IRB 6 and S1. Over 150 man-years went into developing the multi-microprocessor S4, which could control six external axes, all welding parameters as well as the robot's own six axes.

The S4 controller was designed to improve two areas of critical importance to the user; the man-machine interface and the robot's technical performance. A vital key to the former was the "Windows" style teach pendant. It was the same familiar environment as used in PCs with drop down menus and dialogue boxes, so that set-up and operation of the robot was made simpler. At the same time programming was made easier through a new open multi-level programming language, RAPID with the flexibility to develop or adapt functions to meet each user's specific needs.

Dynamic modelling

The concept employed by ABB to improve robot performance with S4 was "Motion Control" using smart software functions rather than purely increasing mechanical performance. The foundation of this motion control is a complete dynamic model of the robot held in S4 and is the basis of QuickMove, a function in which the maximum acceleration in any move is determined and used on at least one axis so that the end position is reached in the shortest time. As a result, cycle time is minimised and not dependent purely on axis speeds.

Another feature emanating from dynamic modelling is minimal deviation from the programmed path, which is applied in TrueMove. This function ensures the motion path followed is the same whatever the speed and obviates the need for "path tuning" when speed parameters are adjusted on-line.

With the dawn of the new millennium, robot productivity and communication needs were becoming ever more vital to lean production. ABB's answer to these demands was the S4Cplus controller, first seen in 2000, which featured new computing hardware to deliver superior robot performance and enhanced communications capabilities. For the first time ABB adopted a standard PC format

4 IRB 2000 arc-welding, AC-powered robot was born out of an egg at a show in Brussels in 1986.

5 IRB 6000 with its modular design concept was introduced in 1991 and became ABB's most successful spot-welding robot.

with a PCI bus and a Pentium MMX processor at the heart of the main control computer. It proved capable of controlling the fastest robots on the market including the FlexPicker.

Coordinated multi-robot control

A further dramatic advance in robot control was made by ABB in 2004 when it launched the fifth generation IRC5 control system. An outstanding feature of IRC5 is its ability to simultaneously control up to four ABB robots plus work positioners or other servo devices – a total of 36 axes – in fully coordinated operation through a new function: MultiMove.

Controlling up to four robots from a single controller minimizes installation costs and brings quality and productivity benefits. It also opens up completely new application possibilities, such as two arc welding robots working in tandem on the same workpiece deliver even heat input and eliminate distortion due to shrinkage on cooling; several robots in concert handling a single flimsy workpiece to prevent bending; and two or more robots lifting a load larger than the capacity of the one robot.

In seeking a lean solution for robot control, ABB developed a modular concept for IRC5 7, in which functions are logically split into control, robot axis drives and process modules, each housed in identical standard "footprint" cabinets. IRC5 controllers may be stacked, placed alongside each other or distributed up to 75 m apart. Installation is made even simpler by the two-cable link between modules, one carrying safety and the other Ethernet communications. The modular arrangement also means the system may be cost-effectively specified to match the customer's immediate exact needs, while still readily expandable to meet future demands.

6 The FlexPicker in action.

7 The modular controller IRC5 has the capability to control multi-robot applications.

Controlling up to four robots from a single controller minimizes installation costs and brings quality and productivity benefits.

Intelligent operator interface

Although complex, setting up and operating a multi-robot cell with fully coordinated motions was made easier for a user by FlexPendant, the world's first open robot operator interface unit, developed for IRC5. The joystick is retained, not just for jogging each robot but also to manipulate all four robots as a single entity in synchronism, a feature unique to ABB.

FlexPendant has its own computing power with an open system PC architecture. It set new standards in ease-of-use and flexibility of operation with a full colour "touch" screen, on which Windows-style menu-driven pages are displayed. Pages with familiar icons and graphics are available for different user levels, and new ones may be created to suit a user's needs and applications. FlexPendant simplifies all aspects of robot cell operation from set-up and program loading through process development and cell operation to reporting and servicing.

Virtual robot technology

In 1994 when ABB brought out the S4 controller, it also introduced "Virtual Robot Technology", a unique concept in which simulation of a robot system on a PC utilizes exactly the same code to that which drives the real physical robot. In 2004, the second generation Virtual Robot Technology was launched alongside the IRC5. In this, even more behaviour patterns are simulated including all aspects of the production process and connected PLCs. This way total transparency between the virtual controller and the real IRC5 controller is achieved. Consequently, programs developed off-line are very accurate and run "first time every time" helping to reduce lead times and set-up costs.

Over the past 30 years industrial robotics has advanced beyond all recognition. Having created the first all-electric microprocessor controlled robot in 1974, ABB has continued its pioneering developments, culminating in the IRC5 multi-robot modular control system in 2004. In the intervening 30 years, positioning accuracies have improved from 1mm to 10 microns, user interfaces from a 4-digit LED read-out to a full Windows touch screen display and computing power from 8 kB to 20 GB or more. At the same time reliability has increased to 80,000 hours MTBF (Mean Time Between Failures) in some applications and costs have plummeted so that today, the robot price is less in actual terms than it was 30 years ago. The world of the industrial robot is well past its early dawn.

For more information see www.abb.com/robotics

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Body builders

Robot-based standardized manufacturing modules for easier and faster installation of new production assets

Bernard Negre, Marie-Pierre Picard

Robot participation in the manufacturing world is at its most visible in the automotive industry. Robots make the entire process look very simple as, with unerring accuracy, they repeat the same procedures over and over again.

Behind the simplest lift and place movement, however, lies a remarkable amount of technology. And the complexity of the tasks continues to grow as the market demands shorter cycle times, more cost efficiency, and increased reliability and flexibility. Besides all this, technical evolution and innovation are forcing manufacturers to rethink the way robots are employed.

Years of technological developments have enabled ABB to produce solutions that simplify and standardize many of the different car development and manufacturing processes. These solutions, designed as "Plug and Produce" standardized manufacturing modules are based on the extensive use of robots.

The rapid evolution of products and markets requires manufacturers to be very agile. However, it also presents them with a dilemma: how to introduce more flexibility into production facilities without having to invest heavily in extra plant and equipment?

For many years, the automobile industry was restricted by the inflexibility of the frames used to build cars. Each car model required a massive steel construction to hold the car parts firmly in place during assembly. Today, robots are strong enough to hold the parts in place while a spot-welding robot applies many dozens of spot welds to keep the parts solidly together before the car is passed on to a further station where thousands of fine welds are performed. Robots have not only become stronger, they can also operate over larger working areas and can position parts with sub-millimeter accuracy. This geometrical positioning ability replaces specialized equipment and greatly simplifies production cell design.

Tooling has also improved. Assembly lines equipped only with welding, material handling or servo tool-welding robots provide an ideal basis for standardization. Lightweight tools and clever tool changers have also made their mark.

Standard Manufacturing Modules

ABB is a leading supplier of equipment for the entire automobile production line, including the so-called body-in-white stage. This latter term is used to describe a "raw" car body, assembled in the "body shop", before it has been treated or painted. The strongly competitive body-in-white market has experienced significant changes including:

- Life cycle cost reduction.
- Shorter lead times between design and production.
- Increased uptime.
- Increased flexibility.
- High quality.
- Simultaneous production start-up of the same model in different locations.
- Simultaneous engineering – new ways to analyze and handle data.
- More product customization.
- Reusability of installations (carry over process) for future vehicles.

These changes have resulted in pressure for processes to be fully standardized and for installations to be significantly less complex. It is simply no longer acceptable to develop new production lines that are capital-intensive, inflexible and with customized automation solutions.

For this reason, ABB has produced solutions that simplify, standardize and optimize body-in-white installations across a wide range of assembly line types, such as framing systems, main subassembly and closure lines.

Elements of standardization

As demand grew for body-in-white equipment to be provided with higher reliability and flexibility in a shorter time, ABB began to develop manufacturing solutions based on robots which can address all the different areas of the body shop. A range of modular basic products has been central to ABB's drive to standardize many different car manufacturing processes. These exploit many technology evolutions, such as high payload robots, modular concepts for grippers, and a simplified Human Machine Interface, and are put together to form mini "assembly zones". The setup is simplified by extensive use of geometrical grippers (movable tooling), which enables the robot to both handle and position parts by itself instead of having to use dedicated machines or equipment. Four basic ABB systems can be used to provide complete Standard Manufacturing Modules for body shops:

- FlexiCell
- FlexFramer
- Robotic roller hemming cell
- Robot Based Measurement System

FlexiCell

FlexiCell is a range of modular Spot-Welding cells for preparing body components and subassemblies 1. Built from standardized components, these cells can be used independently or in combination with other cells to equip assembly lines and preparation islands. They are composed of the following basic subsystems:

- Robot.
- Operator loading station.
- Robot grippers.
- Process units (welding, gluing etc).
- Standard controls and MMI (man-machine interface).
- Operator safety system.
- Cell supervision software.

Batch production is possible thanks to quick-change tools, and up to four robots can work in one unit performing as many as 4000 welds per hour. Each cell is managed by an MMI equipped PLC. Each cell can be configured as a separate safety zone.

FlexFramer

Main assembly lines, constructing, say, complete cars, and which require geometrical grippers, can be equipped with this framing system. Three triangularly arranged interlocking tools connected to the baseframe ensure components are held firmly and accurately in place. The system is the most flexible on the market and capable of bringing new model variants to the market more quickly.

FlexFramer 2 uses three robots (two to pick and place and an optional rear tool robot) to take the bodysides and place them in position while welding robots apply the welds.

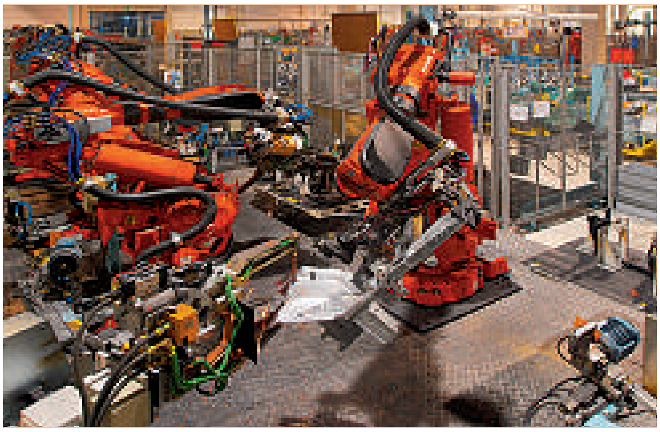
Robotic roller hemming

The process of hemming is used to join two components by folding the edge of one over the other to create a mechanical interlock.

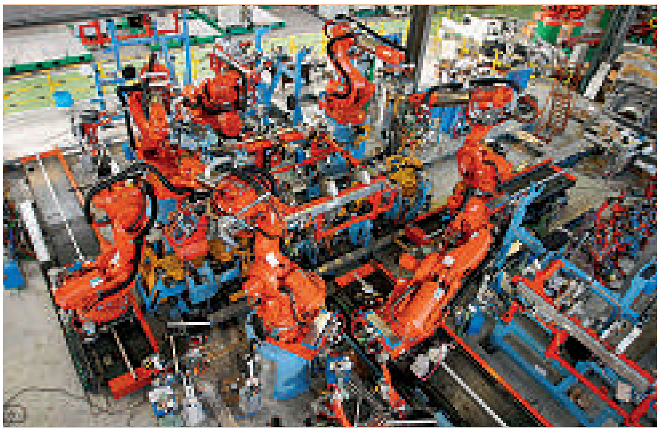
Many assembly lines around the world use ABB's hemming equipment because of its productivity and dimensional precision in the production of doors, hoods, sliding doors and other automotive parts. As well as table top hemming and die hemming systems, manufacturers can buy production cells for robotic roller hemming, a technique which successfully hems corners.

This roller hemming method 3 is highly flexible, with fast set-up capability and low maintenance costs. With a capacity of 5–80 panels per hour, it is suitable for both low and high volume production. It is highly flexible, allowing the production of up to four models on the same line.

1 A handling robot brings the part to a pedestral gun.



2 „All in one" framing station – 4 models – for Holden Australia.



Robot Based Measurement System (RBMS)

As the demands for measurement flexibility and lower manufacturing tolerances increase, manufacturers, in particular those in the automotive industry, are looking for a robot "absolute accuracy" measurement approach similar to what a CMM (coordinate measuring machine) offers.

ABB's answer is an automatic in-line calibration solution known as the Robot Based Measurement System[1]. It is a 3D measurement system which uses 3D triangulation laser sensors to achieve absolute accuracy measurement capability, without calling for any additional correlation or offset compensation.

This solution makes the manufacture of accurate and repeatable workpieces from robots cells simpler and faster. Tolerance to all kinds of changes that must be reckoned with on a real-world factory floor and which could otherwise degrade product quality is improved.

Standardized solutions in action

A few hundred kilometres to the north-west of Madrid lies the city of Valladolid. It is here that Renault assembles its compact and spacious Modus car. Renault's production facility in Valladolid is special from an ABB point of view in that it is an ideal example of the company's body shop modular concept in operation 4. To be more specific, the facility employs both the FlexiCell and FlexFramer standardized solutions.

Reference:

[1] See "Measures of accuracy", pp 13–15.

3 Roller hemming robot carrying ABB patented hemming tool.

A large part of the body shop, including underbody, framing line and respot was installed in 2003. In addition, front end, central and rear floor assembly lines were also provided. Over 100 FlexiCells are used in the production units and because they were fully tested by ABB prior to shipping and then shipped whole to the plant in Spain, the total installation and commissioning time needed for the cells was minimized.

For the underbody, framing and respot lines, Renault chose ABB's standard underbody pallet system, and therefore benefits from the "locate and weld" concept. Here, one robot is equipped with a geometrical gripper to accurately locate a part for other robots to weld.

For body framing, ABB installed the FlexFramer system 5 thereby giving Renault maximum flexibility in their production line, especially at a time when new models need to be brought quickly to the market.

The total production cycle in the Valladolid plant is more than 70 cars per hour.

Simplicity for the future

No more will dedicated jigs or complex equipment be required on the assembly line. These are now replaced by ABB's standardized Plug and Produce modules, which can be configured in a simple and flexible manner.

Adapted and defined on a customer-by-customer basis, this concept is changing the way body shops are implemented and organized. And they are also changing automakers' product strategies in terms of diversity, manufacturing capacity, simultaneous installation in different plants, and very short lead time. Such a concept contributes to the evolution of the body-in-white technology and fully responds to these market requirements. It simplifies the complete car development and manufacturing process and prepares the automotive industry for the future.

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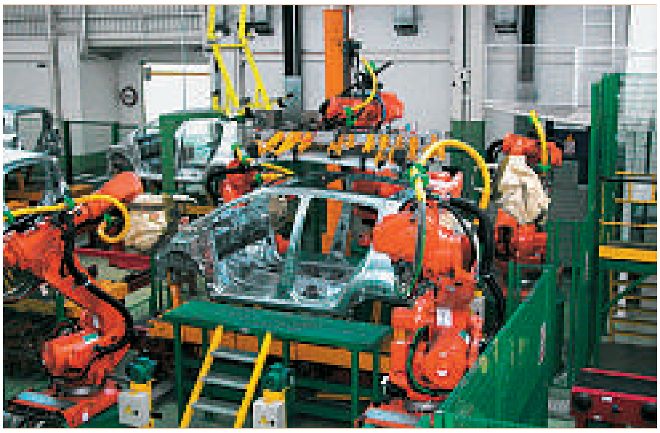
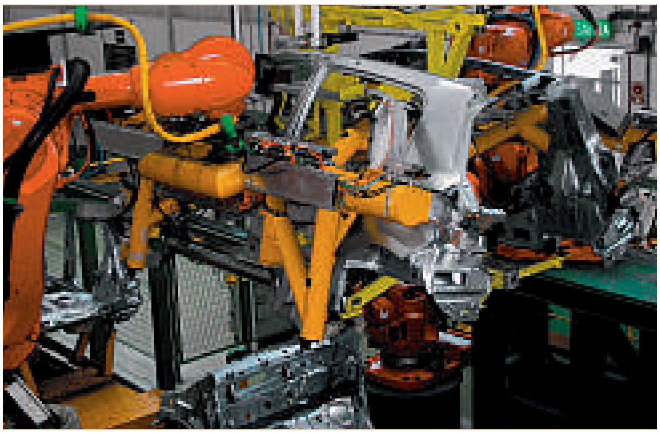
4 Roof positioning on car: the required accuracy is reached by ABB robots.



5 Even car body framing operations are done by ABB heavy load robots in the FlexFramer.



Measures of accuracy

Achieving "absolute accuracy" with a robot based measuring system

Fabrice Legeleux

Have you ever wondered how they make car-doors fit exactly into their frames?

The shape matches precisely and the door opens and shuts perfectly every time. In everyday use we may take this for granted and accept nothing less. On the assembly line, however, doors and thousands of other parts must be matched with the car body without requiring reworking or adjustments. These parts may be made from different materials, on different production lines, in different factories, by different companies and on different continents. All of these suppliers must be able to produce parts and ship them in the confidence that they can and will all fit together and work exactly as required. Strict margins of manufacturing tolerance are required.

Keeping parameters within specifications is primordial for quality assurance. Where parts are robot manufactured, this relies on precise positioning of robot and workpiece.

Such precision is not as simple to achieve as it may seem. The real world trajectory of the robot may diverge from the predicted trajectory for a variety of reasons: The position of the robot on the factory floor may not match its intended position precisely. Furthermore, the robot is exposed to wear, and thermal and environmental effects – settings that delivered correct results in the morning may no longer do so in the afternoon. Continuous re-calibration is required.

Increasing demands for measurement flexibility and lower manufacturing tolerances are fuelling the development of new measuring systems. Industrial manufacturers, in particular automotive 1, are looking for a robot "absolute accuracy" measurement approach similar to what a CMM (coordinate measuring machine) offers. Indeed, all vision based robot measurement systems currently allow "only" relative measurements – requiring a tedious initialization phase using a scribed part and a CMM correlation to link the measurement data to the CAD data.

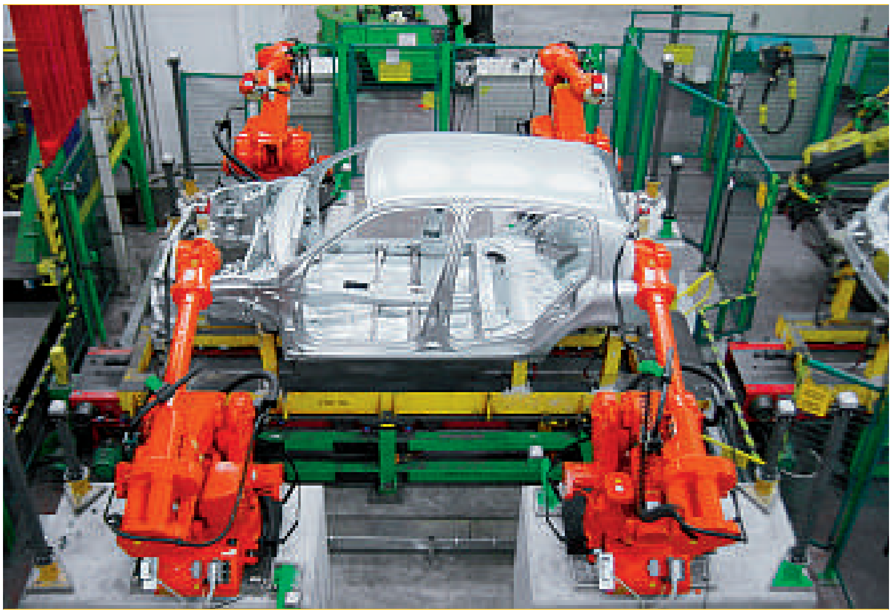
ABB's answer is a proven automatic in-line calibration solution allowing – for the first time – a 3D robot based measurement system using 3D triangulation laser sensors to achieve absolute accuracy measurement capability, without calling for any additional correlation or offset compensation.

The sources of errors

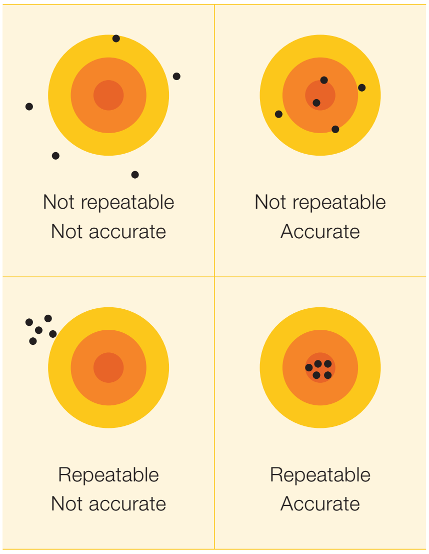
Industrial robot actions are highly repeatable but typically show a poor accuracy 2. The total error is approximately the sum of the inaccuracies of the individual components of the robot, from the concrete base slab to the tooling at the end of the robot arm. Errors may be systematic (deviations in robot component dimensions or their base positions), or fluctuating (thermal drift or variations in ambient temperature).

When a program is transferred from simulation to a real robot station, considerable disparities between simulat-

1 Robot manufacturing places high demands on repeatability and accuracy



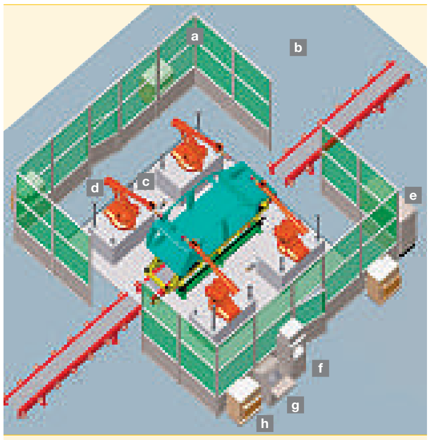
2 Accuracy and repeatability: the work of most industrial robots is repeatable but not accurate. RBMS provides them with the means to hit the centre of the target every time.



3 Measurement monuments with low expansion coefficients are used for calibration.

4 A robot cell using RBMS.

a Protection enclosure
b Workshop Floor
c Metrological concrete slab and robot risers
d Calibration monuments
e Electrical cabinet
f IPNet controller
g Station console
h Robot controller



The base plate is a concrete slab. This provides a metrological base and is protected against vibrations from the workshop floor by a peripheral joint. It is not connected to the enclosure for the same reason. The base plate is, however, linked to the robot risers (also concrete) to provide common rigidity. Calibration monuments are attached to the risers assuring stability of geometric relations over time. The monuments themselves are made of silicon carbide for low thermal expansion.

ed and real results can be observed. Deviations of several millimetres can ensue – sufficient to make manufactured parts unusable: a door that is too big won't shut and one that's too small will let the rain in.

To surmount these problems, a system is required permitting the real 3D locations of all parts of the car to be measured with absolute accuracy.

Calibration and compensation

Accurate reference monuments 3 are located within the robot cell 4. These are first measured with a stationary laser tracker, returning accurate measurements relative to the car's position. The same positions are then measured again by the robot's "eye". This eye is carried by the robot and moved to the object to be measured, so returning the exact robot settings required to reach these positions. The two sets of data obtained are used to create a so-called "inaccuracy map" of the robot.

This map correlates CAD positions to real-world robot settings. It is the basis of the "absolute accuracy" of the robot's positioning.

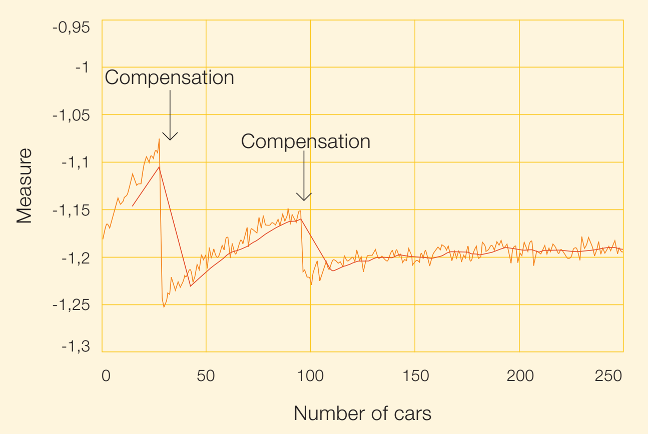
The procedure is used at the start of production and is repeated periodically to ensure and monitor repeatability. This approach not only assures the robot's positional accuracy, but also the repeatability of its performance over time irrespective of wear, temperature and other environmental factors.

5 illustrates a cold start production. When robot thermal drift exceeds 0.1 mm, this is automatically detected by the robot controller and corrected by the compensation software; keeping total error within a much narrower band than would otherwise be possible.

Volumetric accuracy test

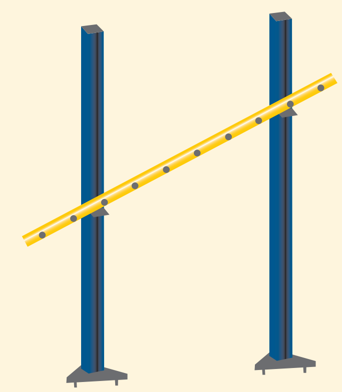
To additionally observe accuracy and repeatability of this equipment, a volumetric accuracy test is used. This "hole bar test" uses a bar with ten equidistant holes and an ABB IRB 4400 robot carrying a Perceptron FlexiCam sensor.

5 After a cold start the robot warms up leading to thermal expansion of its parts. Settings that led to perfect results initially are to be corrected as the robot warms up. Drift is maintained within a very narrow margin.



The bar is made of material with a low thermal expansion coefficient. It is placed in several positions on a rigid fixture 6 throughout the working envelope of the robot and provides a measure of the repeatability of the robot's self-adjustment. The test is based on the norms used for classic CMM, such ISO 10360-2 and the ASME B89.4.1 as well as the robot performance standard ISO 9283.

6 The hole-bar test provides a measure of accuracy and repeatability of the robot's self-adjustments.



Implementation history

- 2001: First performances tests with IRB 4400 and Perceptron vision system.
- 2002: Validation of absolute accuracy performances with Dynalog.
- 2003: Industrial validation with Renault.
- 2004: First four industrial robots stations at Renault Flins plant.

Advantages of "absolute accuracy"

The continuous calibration and compensation cycle at the heart of the RBMS philosophy makes this type of production more robust:
- Greater tolerance to ambient temperature reduces demands on air-conditioning and temperature control.
- Downtime for interventions such as replacing sensors is shortened due to automatic calibration.
- 100% of production is controlled.

Operational flexibility is also enhanced because:
- Different car models can be produced on a single line and new models easily added to running lines.
- Instant feedback is provided when tooling adjustments are made (necessary, for example, when a new model is introduced).
- Calibrated measurement points are easy to add using off-line programming.
- Standard robots can be used instead of those with a built-in "absolute accuracy" option.
- No more time-consuming and cumbersome correlation with CMM or "Gold Model".

Conclusion

ABB's robot based measurement system (RBMS) makes manufacturing accurate and repeatable workpieces from robots cells simpler and faster. Tolerance to all kinds of changes that have to be reckoned with on a real-world factory floor and which could otherwise degrade product quality is improved. And despite living in a sub-optimal real world, production to within 0.4 mm of the ideal CAD world is possible.

ABB is making sure your car doors shut perfectly the first time and every time!

For more information see www.abb.com/robotics

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Learning skills

Robotics technology in automotive powertrain assembly

Hui Zhang, Zhongxue Gan, Torgny Brogard, Jianjun Wang, Mats Isaksson

The past 40 years have seen industrial robots establish their superiority over humans in most areas of manufacturing requiring endurance or repeatability. One important application domain, however, has so far lagged behind the industry's expectations: mechanical assembly. As fast, precise and dependable as they are, traditional industrial robots just don't seem able to perform certain assembly operations as well as a skilled human worker.

A task as simple as screwing a light bulb into a lamp socket shows why. Applying the right amount of force and turning the bulb at just the right time, at exactly the right angle, is something a human does intuitively. How can a robot be programmed to do this?

For robots to successfully emulate humans on an assembly line, they need to have force-sensing capability and exhibit compliance. They must be able to direct forces and moments in a controlled way, and react to contact information. New robot force control technology from ABB shows how.

Assembling automotive powertrains is traditionally manual work, performed by skilled, experienced operators. This is because gears and other critical components of the clutches, torque converters and so on, have to be aligned with very high precision in a constrained environment. Such operations, however, take their toll on human labor. Tedious and fatiguing, they can lead to repetitive-motion stress injury as well as lower product quality and efficiency. A robot able to perform at the same level as a human operator would obviously make the prospect of automation in this application area very attractive.

The problem with position-controlled robots

If a position-controlled robot tries to align a pair of gears and its control program does not have precise information about the gear-tooth positions, the robot's only option is iterative trial and error, repeated until the relative tooth positions are found. Any attempt by the robot to mate the gears as long as they are misaligned will cause one gear to press hard against the other, generating unacceptably high contact forces. Even if the teeth were chamfered to facilitate mating, misalignment would still produce large side forces as the robot struggled to move the gear along the preprogrammed path toward the centerline of insertion. More than likely, the gears would even jam unless some means of mechanical compliance is provided.

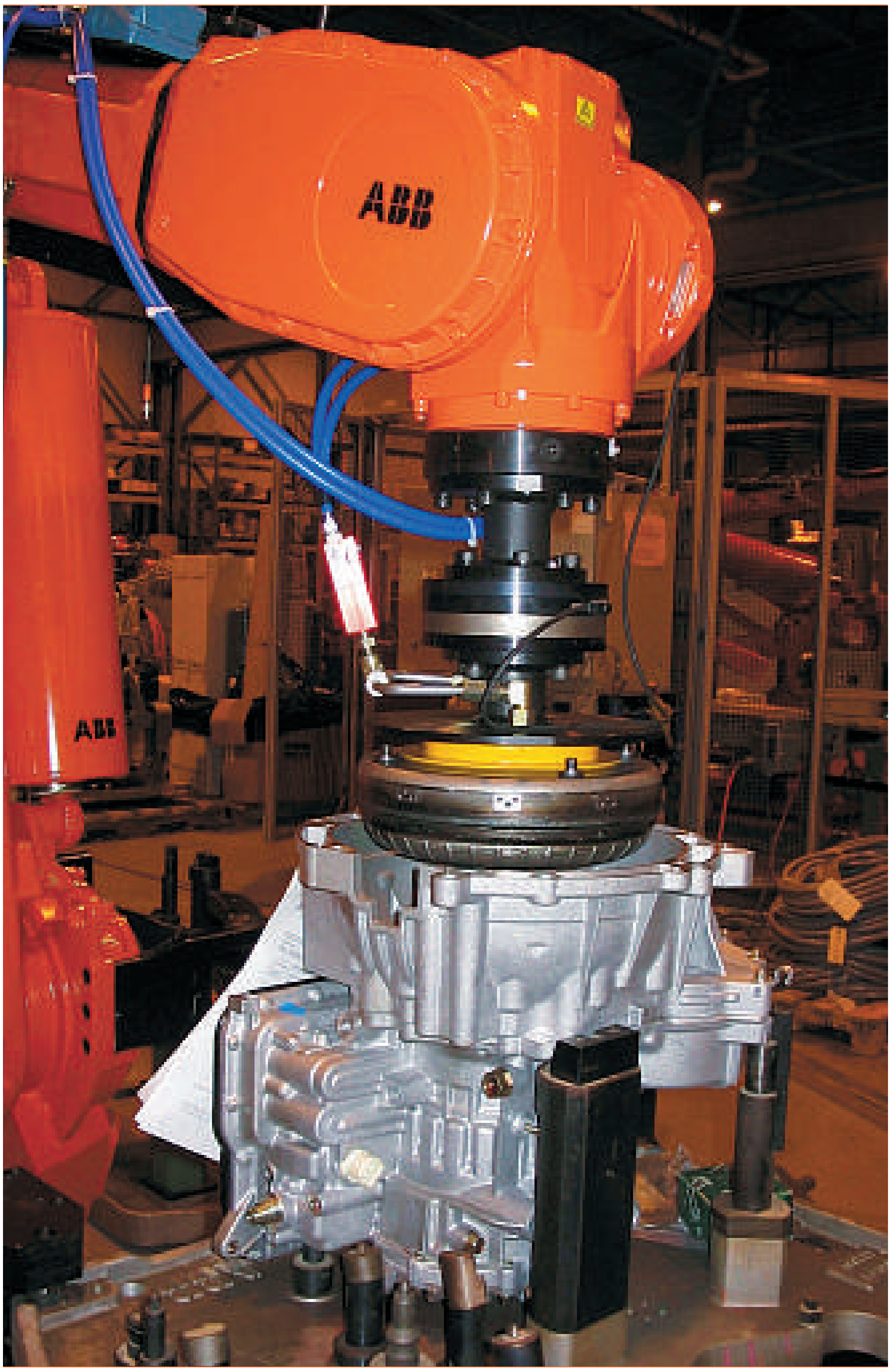
The remote center compliance (RCC) device was developed to solve this problem. Fitted with elastomer shear pads to reduce the contact forces, it enables an assembly machine to compensate for positioning errors caused by lack of accuracy, by vibration or by inadequate tolerances. As soon as its compliance center approaches the contact point, the (male) part being inserted aligns automatically with the female part by yielding to the high contact forces that are generated by lateral and rotational misalignment. Neither the parts nor the tool are damaged.

Unfortunately, as useful as the RCC device is, it cannot be used for many of the assembly tasks found in an automotive plant. There are several reasons for this. First, the geometries of the assembly parts are complex and vary widely, making it necessary to frequently change from one part-specific device to another. Also, since the device itself is not able to position and rotate the parts relative to each other, assembly takes longer. All in all, there is a higher risk of malfunctioning.

Learning from us

Humans are remarkable for their agility of thought and action when faced with assembling complex parts – applying insertion force where appropriate, yielding before a part becomes jammed. Human assembly workers instinctively learn to make the best use of compliance, sensed forces and moments, and tactile contact clues from edges and boundaries, to quickly obtain the desired result. One feature that clearly distinguishes humans from industrial robots is our ability to sense a contact force and respond to it. For robots to emulate human behavior, they therefore need to exhibit similar force-sensing capability and compliance and be able to direct forces and moments in a controlled way, as well as react to contact information. All of this calls for a change in the traditional robot position control paradigm.

1 F/N torque converter assembly with force controlled IRB 6400.

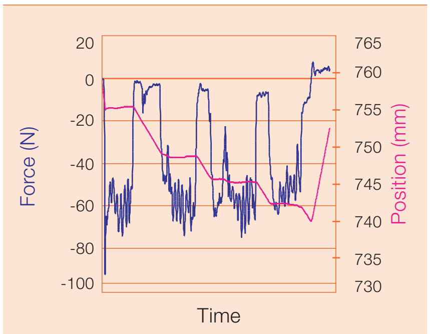


The ABB solution

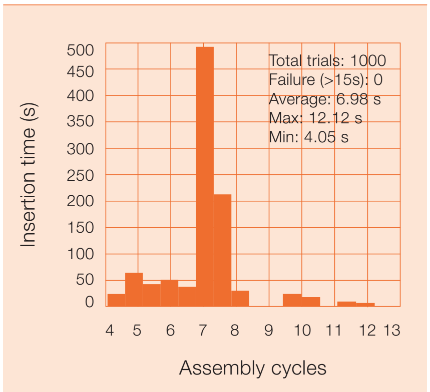
As the supplier of the world's largest installed base of robotic products, ABB continuously researches and develops new technology for robot applications. Part of this ongoing activity includes university collaborations, and in one of these ABB scientists and engineers teamed up with researchers from Case Western Reserve University in Ohio, USA, and Lund University in Sweden, to develop a new force/position hybrid platform based on ABB's S4Cplus robot controller. Around the same time the team also began collaborating with Ford Motor Company to learn more about the specific application requirements. This project yielded a general solution for force control-based assembly applications.

The outcome of this work is a solution that makes ABB robots "sensitive" as well as powerful. What is more, this new sensitivity is gained without any loss of existing capability or functionality. Hallmark features of ABB robots – advanced control for fast acceleration, enhanced communication and high reliability, to name a few – are all retained.

2 Assembly force for a forward clutch with advanced force control.



3 Cycle time statistics for F/N torque converter assembly with an IRB 6400 robot with vacuum gripper.



The technology was initially tested on IRB 4400 and IRB 6400 robots, with payloads ranging from 30 to 200 kg, used to assemble different automotive powertrain parts. These tasks, which can be considered complex, included inserting forward clutch hubs and the assembly of F/N torque converters 1. The tests demonstrated consistently superior performance in terms of cycle time, acceptable insertion force, reliability and ease of programming.

To emulate human behavior, robots need to exhibit force-sensing capability and compliance, be able to direct forces in a controlled way and react to contact information.

Harmonious position and force control

While the literature on robot force control is formidable, the results have generally been less than impressive. Achieving acceptably fast robot movement while assuring contact stability has persisted as a challenge. Many promising intelligent-control methods have been investigated, but superimposing slow force control on position control has typically resulted in poor performance.

The concept of impedance and admittance[1)] is also helpful in understanding force control in a robot. Along each degree of freedom the instantaneous power flow between two or more physical systems can be defined as the product of two conjugate variables, an effort (force) and a flow (velocity). An obvious but important physical constraint is that no one system may determine both variables. Along any degree of freedom a manipulator may exert a force on its environment or impose a displacement or velocity on it, but it may not do both. Thus, an assembly robot should have the property of admittance, accepting force (input) and yielding motion (output). The understanding is that once contact force is sensed during assembly, the robot's motion should be changed in a controlled manner so as not to further increase the contact force.

Using the concept of maximum achievable passive admittance as a foundation, ABB's engineers constructed intelligent control methods that integrate seamlessly with existing advanced position control methods and guarantee stable, gentle contact in most common production environments. The design also ensures a smooth transition between the force control and position control modes.

Easy to program

Although a robot with active force control has the advantage of being versatile and programmable for different applications, it requires a more advanced control system and adapted programming to specify how the robot should interact with external constraints. Research so far has focused on the control strategy and its capacity for enabling the robot to establish stable, gentle contact while interacting with the environment. At present, there exists neither a high-level programming language nor a suitable programming concept with which to exploit the force control capability.

Introducing force feedback only enables an industrial robot to respond to an environmental force. In no way does it tell the robot how to move when mating parts. A force control enabled compliant robot can therefore only try to avoid high contact force; it lacks a mechanism for mating parts, such as gears, according to their geometrical contours. Jamming of the assembly pieces is prevented, but no help is provided with aligning them. The presumption that a robot's position can be modified via the interaction forces is difficult, if not impossible to put into practice when mating uncertainty is high and there are so many possible contact scenarios that they are mathematically impossible to handle.

The ABB solution relieves users of the burden of complex programming by introducing the concept of attraction force. Coupled with admittance-based fast force control, this ensures not only that contact is made gently, but also that the part being mated is positioned for accurate alignment. As soon as all the alignment requirements are satisfied, the robot can begin its part-

Footnote

1) In force control, the relationship between force and velocity is very important as a means of understanding system behavior in terms of stability and performance. The impedance is defined as force divided by velocity, while admittance is its inverse.

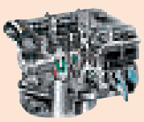
specific search and execute the assembly. A typical assembler program could look as simple as this:

```
Set attraction force;
Set search parameter;
Set destination;
Move to start point;
Activate force control;
If contact
        Activate search;
Endif
If destination is not
reached
        Keep searching;
Endif
Deactivate search;
Deactivate force control;
Restract
```

4 Application map for advanced force control in the automotive industry.

Powertrain assembly

Engine

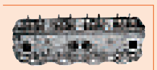


- Bearing Installation
- Bearing liner Insertion
- Gear pump assembly
- Piston assembly
- Spark plug assembly
- Valve Insertion
- Reverse servo installation

Trans/gearbox

- Bearing Installation
- Bearing liner Insertion
- Clutch plate assembly
- Forward clutch hub assembly
- Splined shaft insertion
- Sun gear assembly
- Torque converter assembly
- Transmission accumulator assembly
- Transmission differential assembly
- Triple clutch assembly

Cylinder head



- Bearing Installation
- Bearing liner Insertion
- Cylinder head assembly

Axle

- Bearing Installation
- Bearing liner Insertion
- Planetary carrier assembly
- Planetary pinion insertion
- Splined shaft insertion
- Sun gear assembly

Misc.

- Bearing Installation
- Bearing liner Insertion
- Piston assembly

Strength plus agility

Clearly, the lighter the parts being assembled, the easier it is to apply just a slight contact force. This is even true for manual assembly. When assembling heavy parts it is no easy matter to limit the allowable contact force to less than the weight of the part being moved into position, as it requires the operator to support that part, against the force of gravity, while going through the assembly steps. The work can be tricky as well as backbreaking.

An example is the assembly of Ford's F/N torque converter case, which weighs about 25 kg. Inside this case is a double splined gear-set into which a pump gear has to be inserted. The pump gear seal is critical and great care has to be taken to ensure it is not damaged in any way during the insertion. An internal splined shaft has to be fitted at the same time, complicating the assembly.

> Tests carried out with advanced force control in industry have demonstrated its ability to improve cycle time and agility in different assembly applications.

ABB's robotic solution for this task started with the choice of robot, an IRB 6400. This was selected on the basis of its payload capacity of 150 kg – the weight of the parts it can support, without help, and without contributing to any undesirable contact forces. Tests showed that the IRB 6400 is able to handle a total weight of 75 kg (the combined weights of the part, gripper, force sensor, etc) and still limit the contact force to less than 200 N.

Advanced force controlled ABB robots, as the tests demonstrated, are capable of extremely delicate assembly operations, even when heavy parts are involved. Arm movement is 'feather-light' but still powerful, a combination that suits assembly applications in a wide range of industries.

Superior performance, reliable operation

The tests carried out with advanced force control in the automotive industry have convincingly demonstrated its ability to improve cycle time and agility in different assembly applications.

In one application involving the insertion of a forward clutch 2, a work cell with an IRB 4400 robot averaged 5.7 seconds for the insertion with a reaction force of less than 100 N on initial contact and under 80 N during assembly (performed manually, insertion typically takes 15 to 20 seconds). In another, F/N torque converters were assembled in an average time of 6.98 seconds with the contact force limited to 200 N 3. Here it is worth noting that, in addition to the part itself weighing about 25 kg, the allowed positional tolerance was +/–2 mm.

ABB's S4Cplus robot controller is acclaimed throughout the manufacturing industry as the most reliable on the market today. The add-on force control option was developed to enhance this reputation. Leaving nothing to chance, its supervisory functions also monitor the robot for potential sensor error and communication error in addition to the possibility of operational error.

Benefits for a broader market

Developed primarily for assembly applications in the automotive industry 4, advanced force control has potential benefits for many other areas of industry. Quick market acceptance is expected, especially where absence of the "human element" in mechanical assembly – the ability to "get it just right, first time" – has been a problem in the past. In bringing this innovation to market, ABB is once again underscoring its position as the industry leader in robotics technology.

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For more information see www.abb.com/robotics

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Welding sees the light

Precision welding with lasers and robots

Fabrice Legeleux

The automated production of complex metal parts would hardly be possible without robots. Robots repeat the same movement sequences endlessly and tirelessly, delivering high quality workmanship at low cycle times. However, with robot technology alone, this would hardly be possible …

The tools used by the robots are an equally important part of the process. They must fulfill the same high demands on accuracy, repeatability and reliability as the robots themselves, and they must interface optimally with the robots.

Welding requires a heat application of around 10^3 W/cm². If too much energy is applied, the metal evaporates. If not enough is applied, the heat is conducted away too quickly. In laser welding, a powerful laser delivers this energy. Laser welding technology must additionally consider such aspects as focusing and controlling the position of the welding spot.

Different laser welding technologies exist. One common approach is the CO_2 laser. This technology, despite what its name may suggest, typically uses a gas mixture with 70% He, 15% CO_2 and 15% N_2. A drawback of CO_2 lasers is that the light cannot be transmitted along fiber optic cables. Instead, a system of mirrors is used. Very precise coordination is necessary to direct the light to the correct location.

The Nd:YAG laser (neodymium yttrium aluminum garnet) solves this problem. It is a solid state pumped laser whose light can be transmitted along flexible fiber optical cables. Because of this, Nd:YAG lasers are finding increasing use in body in white applications.

The technology does have its drawbacks: The efficiency of an Nd:YAG laser source is limited to around 2–3%, and the light quality is inferior to that of a CO_2 laser. The flexibility offered by being able to use fibre optics make many customers prefer this technology however.

To offset the low laser efficiency, the technology must strive for the highest possible productive laser uptime. This is achieved using a mirror that switches the ray between cells: ideally, one cell starts welding the moment the other cell stops – and the light is never wasted!

The new IRC5 industrial robot controller provides unparalleled capabilities with its MultiMove functionality[1] precisely synchronizing multiple robots with extreme accuracy. It also controls the mirror that switches the ray, ensuring that this perfectly matches the movements of the robot.

The use of a fiber optic connection has another important advantage: The welding source is not rigidly attached to the robot 1. This saves on time-consuming alignment and adjustment work when the welding source is changed.

Safety first!

The light from such a powerful source as a welding laser diode can cause permanent blindness. Hence, greatest care is taken to ensure the safety of staff at all times. Even reflected light is hazardous; with this in mind, the cell is uncompromisingly implemented to eliminate risk of contact. The enclosure is made of multiple layers of sheet metal supported by a steel frame. According to risk-analysis recommendations, various sections may be additionally reinforced.

Robust automatic doors are provided for workpieces to enter and leave the cell. Their size is varied to suit the product being manufactured and can range from small up to garage-door size. Additionally, a service door is provided for staff to access the cell. A safety mechanism monitors these openings and ensures welding cannot take place while any door is not completely shut and locked. Any attempt to open a door during operation stops the process instantly.

Perfect positioning

Besides the welding robots and their associated equipment, the cells also contain positioners to optimally orient the workpiece for welding and so reduce cycle times.

Perfect coordination between the robots and positioners in the cell is required to produce a suitably accurate weld. This coordination is provided by ABB's IRC5 robot controller, which can control up to four robots or positioners simultaneously.

Additional accuracy is gained using Seam Tracking (ST) technology, in which optical recognition guides the welder perfectly along the seam.

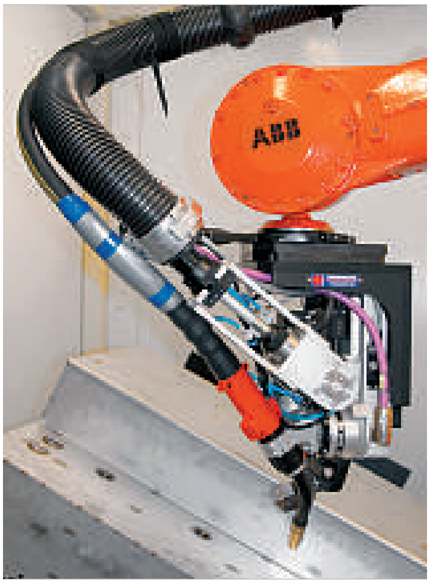
Seam Tracking

In Seam Tracking, the robot "sees" and follows the intended welding seam using a focus optic. This optic is the same that is used to focus the main welding beam (Beam Path Integrated Vision). The lack of additional camera optics leads to a compact tool design.

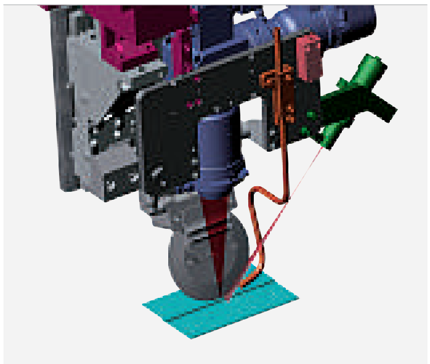
Seam tracking is supported by a powerful software that analyzes the pictures fed to it by the camera and adjusts the spot position accordingly. A cycle time of about 40 ms leads to an exceptional responsiveness.

A roller positions the welding tool on the seam line 2 and presses the two pieces of metal together at a defined pressure to assure optimal bonding. The pressure is pneumatically regulated and adjustable. The roller angle is fixed but the optics tilt to follow the contours of the workpiece. Filler wire, protective gas nozzle, welding beam focusing unit and workpiece sensor are all attached to this press device (PD) module, assuring they are always in the intended positions, and that they all "float" along

1 Laser welding fixture.



2 Press device module.

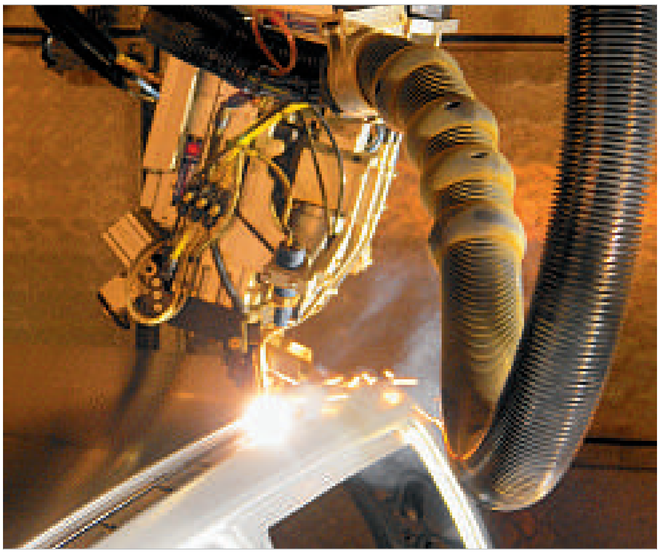


3 Welding cell in China.

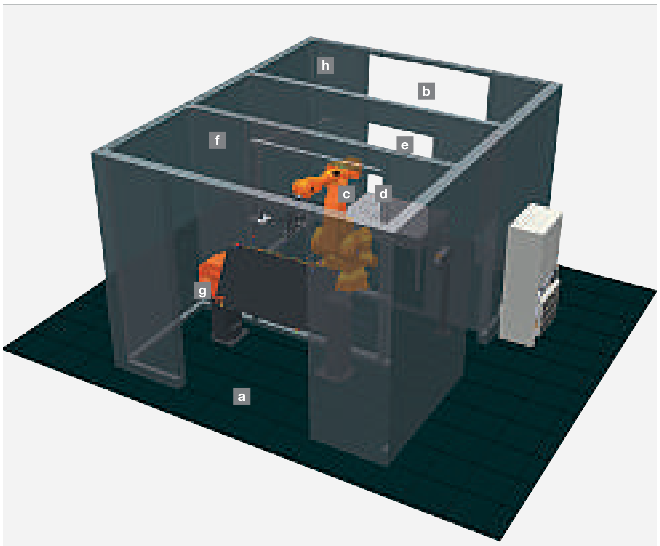
Reference:

[1] See Team mates, pp 53–56.

4 Laser welding of metal boxes.



5 A look inside the cell of 3.



the seam together. Different PD module designs are available depending on the application. For example, a flange joint weld needs a two-wheel configuration – one wheel for every sheet, whereas a single wheel is normally sufficient for an overlap joint.

The following customer use-cases describe laser-welding applications realized in cooperation by ABB and Permanova.

Laser welding cell in China

A customer in China uses a robot laser welding system for manufacturing several types of stainless steel boxes 4. The requirements placed on the welding equipment are very high because no oxygen may leak into the boxes.

The robot cell 3 contains two welding stations. Each has its own door for loading and unloading workpieces 5a 5b. A welding robot is located between the stations 5c and can access either station through door-protected openings in the walls of the workstation 5d 5e.

In one station 5f, the boxes are welded. To assist this process, an adjustable positioner 5g orients the workpiece. While this station is being loaded or unloaded, the robot switches to the other station 5h, where other assembly parts and fastening elements are laser welded. Using this technique, complete subassemblies can be laser welded, providing savings in assembly work and logistics.

The laser beam from a single 3300 W diode pumped Nd:YAG laser is guided through a flexible optical fiber to the welding tool. The laser output is switched between the stations in the cell, so making optimal use of laser uptime, and accomplishing two tasks in a single work cycle.

The cell is equipped with a Permanova WT03 Laser Welding Tool and an ABB robot. The system uses Seam Tracking technology and the AW hybrid-welding feature with a MIG power source.

Using a laser for welding assures tight seams while causing very little heat deformation. It also only requires access from one side, so reducing handling requirements.

Renault Megane roof welding

Karmann is an important supplier of components and services to the automobile industry. A welding system from ABB and Permanova is in use at their Rheine plant in Germany. It welds the thin zinc-coated steel frames that hold the Megane's "glass roof". The customer chose this solution because only the seam-tracking system could deliver the required accuracy.

The slender workpieces can easily be deformed by in inappropriate welding process. The small and precise welding spot as delivered by a guided laser was the appropriate solution.

Variant cutting at Volvo

In Volvo's Torslanda plant, robot-welding systems from ABB and Permanova are used for variant cutting of semi-assembled car bodies. To cut costs, the cross-country model, XC70 shares side-panels with the standard V70, saving costs in tooling and handling.

Permanova AB

Permanova Lasersystem AB delivers robotized laser processing systems globally, mainly for laser welding (including hybrid welding and brazing), laser cutting and laser marking. Permanova also designs and manufactures laser process tools and calibration tools, and supplies service and spare parts.

PERMANOVA Lasersystem AB is based in Mölndal near Gothenburg, Sweden.
web-site: www.permanova.se.

The variant cutting system is based around two robots, one on either side of the line. These share a laser source and cut to an accuracy of 0.1 mm.

This process requires the cutting of curved trajectories. It is extremely difficult to guide a cutting unit so precisely. Failure to do so, however, leads to jagged corners. The ability to fulfill this requirement gave this product a clear advantage over competitor's solutions.

After this process, the cut-out part is retrieved by a dedicated robot fixture. The collected parts are counted to make sure none has been left inside a car.

Customer stories are courtesy of Permanova AB.

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Unique and ingenious

Using robots to produce small batches or even single units – once unthinkable – is now reality!

Göran Bergling – Andon Automation AB

Until recently, any robot operator would have told you that the great strength of robotics lay in mass production. In the automobile industry for example, robots – once set up – produced hundreds of thousands if not millions of identical items with hardly any human intervention. When it came to handling smaller batches, however, the high costs of programming and verification made robots increasingly inflexible and uneconomic; the idea of producing single units was entirely out of the question. A new generation of programming tools have changed that paradigm.

Today robots work efficiently also with small batches. For example, welding robots are used in shipyards and for building bridges – areas where practically every unit built is different from any that was made before. Despite the uniqueness of every job, robots are providing customers with market leverage through lower costs and higher quality and flexibility.

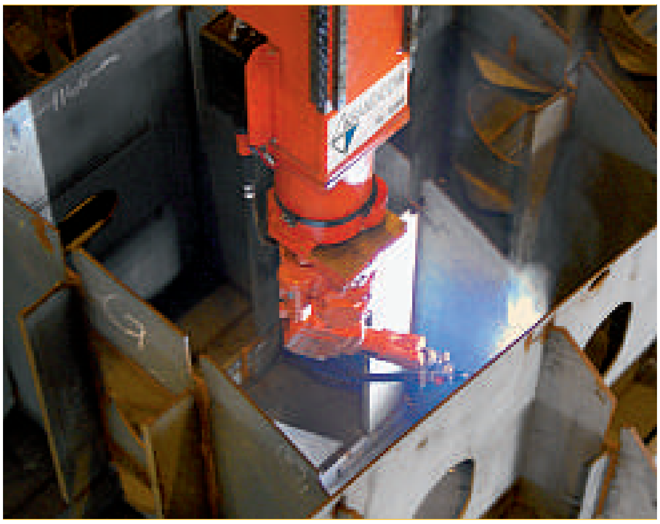
How is this achieved? The answer lies in the use of powerful software to support the programming process. Such software can, for example, derive trajectories directly from CAD data and uses 3D simulation techniques to avoid collisions.

Partnership in heavy welding

A component of ABB's strategic direction is to seek out partnership with companies having global reach and which complements ABB's own engineering know-how. Andon Automation AB is such a partner focusing on robotic welding and thermal cutting applications. In these applications, components are produced in large series or small batches. The core competence of Andon is related to the arc welding process, production logistics and handling of external axes. Its employees have, on average, 14 years of experience in robotic arc welding. The company has developed system modules for robot carriers and positioners to handle customer products up to 50 tonnes in weight. In combination with ABB robot technology, a unique market offer is realized. Virtually any size and shape of product is covered by combining standardized modules.

1 Flexible production of trailer sub-components.

2 ABB IRB 140 inside a ship structure.



General Industry – Flexible production
In most installations, industrial robots are employed for mass production. Once the robot is programmed, it can continue welding without production stops for years on end. However, market conditions are continuously changing: In the early 80's, supplying companies had to start adapting to an increase in model variants and orders for small batches.

Making welding systems more flexible means eliminating set-up times: thus the robot is able to produce batches down to a single item. The user gains new competitive leverage such as shorter lead times, flexibility, stock reduction, improved productivity, and the means to produce directly to meet individual customer orders. The result is a drastic reduction in production costs, leading to higher competitiveness on the world market. Over the years Andon and its predecessors have implemented a large number of flexible concepts for different products inside general industry segments 1.

Robotic Welding in infrastructure environment
The technology described above is, however, not applicable to the infrastructure industry (eg, ship-building, offshore, aircraft, boiler, construction industries and bridges). In these sectors, most of the parts needing to be welded are different in shape, size and configuration. Robot welding time per unit is extensive and welds must be applied over a vast area. Conventional programming methods cannot be applied.

In 1987, Andon's predecessor formed an agreement with Kranendonk Production Systems. This company, based in The Netherlands, is a supplier of turnkey automated production systems for the industry, including installation, production start up and customer training. Its portfolio includes offline programming and on line control software for industrial robots and CNC controlled machines. These allow for easy integration with the customer computer systems, supplying the production data for continuous one-piece production.

Together with Kranendonk, Andon engineers have designed and implemented more than 100 systems for single piece production in the infrastructure industry. Examples are the deliveries of complete systems for the welding of ship panels to Newport News, Aker Warnow Werft, Kvaerner Philadelphia, Chantiers de l'Atlantique and Fincantieri 2.

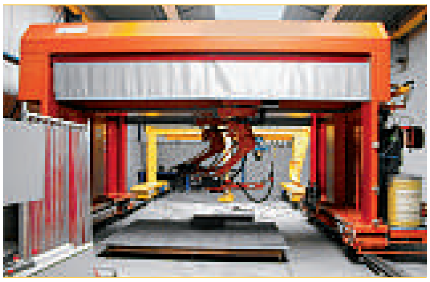
Automatic welding of superstructures demands the highest component quality, both with respect to hardware and software as well as the supplier's ability to integrate the system into the customers' production environment. Depending on the application, various types of ABB robots are used. All offer high stability, unique path following and integration with external axes and the arc welding process. The arc welding functionality allows for control of advanced sensor technologies, which – in combination – assure a high weld quality 3.

The integration and control of robot gantry motions and positioning is of extreme importance. Andon's modular system for robot carriers facilitates robotic welding of extreme product sizes such as double-bottomed hull sections for oil tankers (24 × 16 × 3 meters). All external and internal robot axes are integrated into one unit, thus the system works as one macro-sized robot. Because of the stability and motion performance of the gantry, the system offers full control over all weld positions 4.

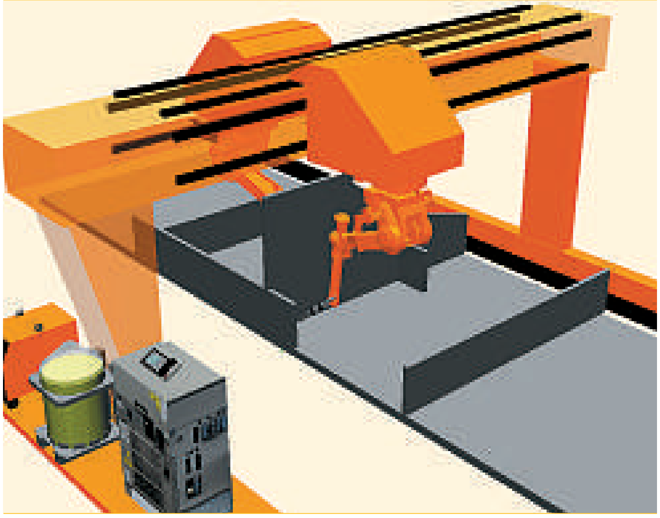
Programming – Integration
The programming method used depends on the application, on the level of automation, and on the number of welding robots. In addition to Robot-

3 IRB 2400 in process of welding ship panels.

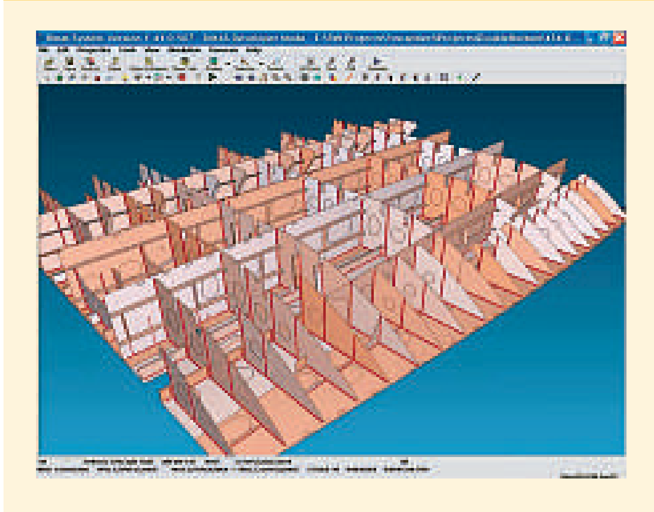
4 Gantry fully dressed during factory acceptance test.



5 Robot Studio model of web production cell.



6 RINAS model of ship structure.



Studio from ABB, two software products from Kranendonk, ARAC and RINAS, are used.

RobotStudio is an offline programming and simulation system that is based on VirtualRobot technology. That is, it incorporates the real software that is used to run robots in production. It is thus ideally suited to verify that generated programs will run as intended, that the robots can reach all programmed points and that there is no interference with fixtures and other objects in the workspace of the robot 5.

ARAC is a parameterised macro-based programming system, where the operator directly defines the work order, or where work orders are created by importing and filtering CAD data. Manual input is considerably lower than robot production time. Programming of a new block is performed while the robot is welding the previous block: the robot can work without any production stops.

The ARAC system also takes care of the online production control. Production processes can be monitored, and if needed, corrected through an easy to use graphical interface.

RINAS is a model-based system that automatically generates collision free robot programs. The main objective of this package is to create and maintain a combined model with full control over the 3D workspace and the objects within this space. In practice, this means that Rinas creates a collision free robot program from the customer's CAD data with virtually no programming time 6.

The base of the Rinas software package is the ROMA concept (Robotized Model based Automation). ROMA allows easy adaptation of Rinas software to a variety of industrial processes. The software is CAD system independent and is suitable for a broad range of applications, such as modeling castings, grinding propeller blades, welding double hull assemblies and cutting curved segments.

Chantiers de l'Atlantique

One of the latest deliveries from Andon/Kranendonk includes four double robot-welding gantries for the French based shipyard Chantiers de l'Atlantique. The shipyard is a major global supplier of cruise ships. Last autumn, the Queen Mary II was launched, probably one of the most advanced and modern ships on the oceans 7.

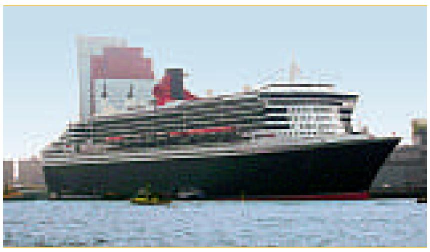
The four double robot-welding gantries are an autonomous production system for the fabrication of web panels. Working in synergy, Andon and Kranendonk have created a system consisting of four individual lines, which should be programmed by one single operator. The four welding gantries are each equipped with two ABB robots and feature the latest welding technologies with torch calibration and seam tracking facilities.

Single piece production is no longer utopia in the infrastructure industry. Andon and Kranendonk have transformed the vision to reality.

Andon Automation AB

The Swedish company Andon Automation AB was formed in 2004 by taking over the arc welding system business from ABB, who had built it on its 1993 acquisition of the robot activities of Swedish ESAB, a world leader in the supply of welding consumables and equipment. ESAB had already in 1987 formed a partnership with Kranendonk of the Netherlands. At the time Andon was established experienced engineers from ABB joined the new company and formed its substantial knowledge and experience base.

7 Cruise ship – Queen Mary II



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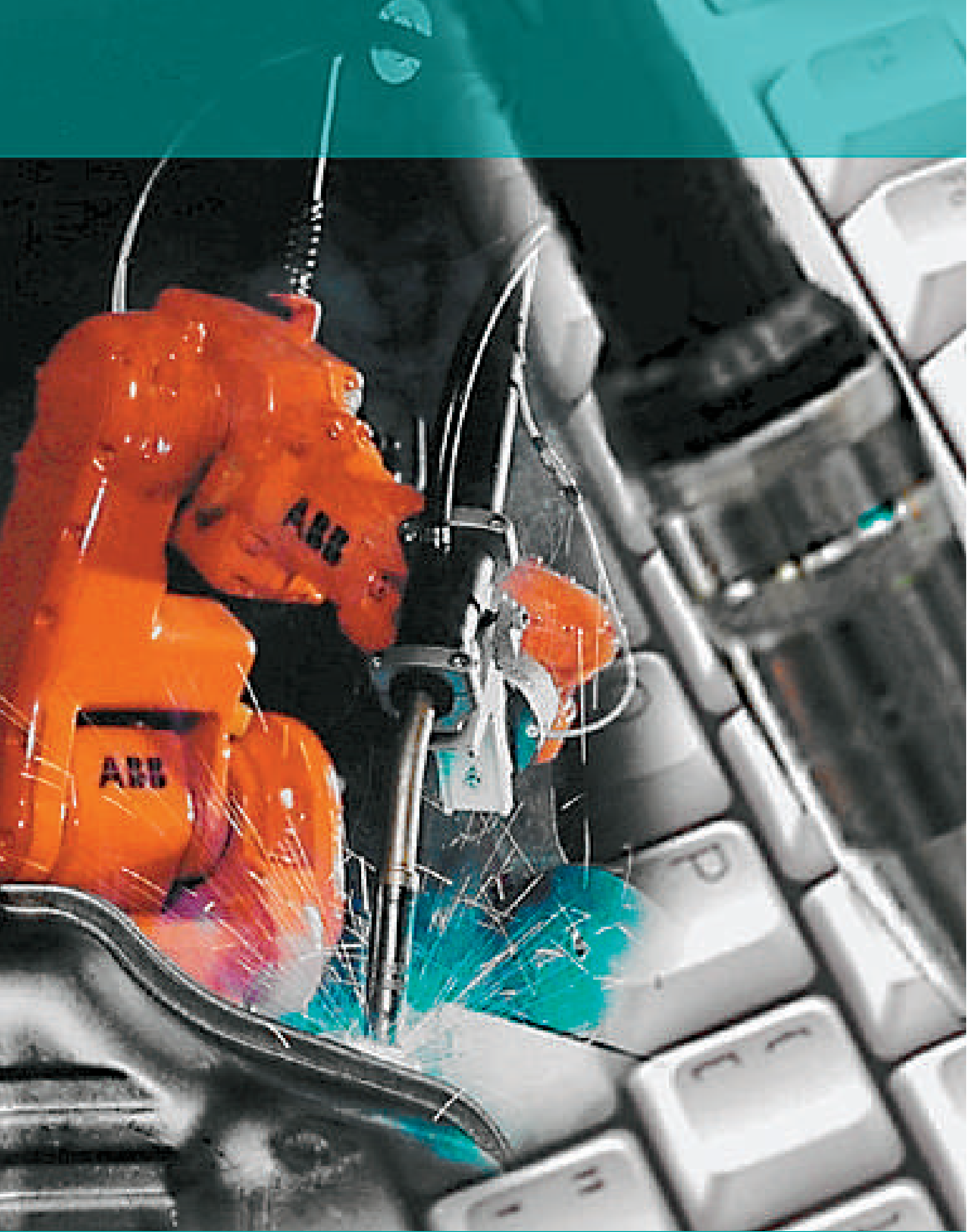


VirtualArc®

Transforms welding from “black art” to practical science

Dick Skarin, Brith Claesson, Göran Bergling

The concept of the traditional welder at work in his smithy is being replaced by a more high-tech view of the craft. Who isn’t familiar with pictures of robot welders at work on production lines? Designers and manufacturers take precise and clean mass-produced welds for granted. But teaching a robot to weld isn’t as easy as it may seem.

Whereas a human welder draws on experience and intuition in choosing the correct welding technique and settings, a robot welder must be instructed in every detail of the procedure. Despite the availability of considerable theoretical knowledge, a series of test runs are often required to determine the correct settings. Such runs waste test materials and block robots that could otherwise be in revenue generating use. The costs and time involved mean that the number of test scenarios must be limited and the optimum can easily be missed.

ABB has developed a software tool enabling programmers and process engineers to reliably determine the result of a weld. VirtualArc® permits a rapid yet detailed evaluation of scenarios. The reduced need for test runs cuts costs whilst optimizing productivity and quality.

“Black art”

For many years, welding using the MIG/MAG process has been considered a “black art”. Most people know that welding is the process of joining two metal parts together, but very few understand the parameters involved and their bearing on the result.

This ambiguity does not just confuse ordinary people: It is said that when ten welding engineers or welders are asked how a given task should be approached, ten different parameter settings are suggested – all of them achieving the same result!

Complex process

The MIG/MAG process is very complex. To fully understand the theory behind it requires in-depth knowledge of arc physics, fluid dynamics, material science, arc-electrode interaction, amongst others. Very few people in the world have all this knowledge, and of those that do, it is unlikely that any have any practical hands-on welding experience.

On the other hand, many very skilled welders in the industry perform perfect welds without any special knowledge of arc physics and the science behind it. Rather, their choices are guided by so-called “feeling” for the process itself. Such knowledge can therefore be found only in the “head” of each individual welder.

Unfortunately, the number of such skilled welders will most certainly decrease in the future, making it increasingly difficult for the welding industry to be successful.

The challenge

Welding equipment suppliers must combine the science behind the MIG/MAG process with practical expertise: Welding must evolve from today’s “black art” to a modern fully controllable manufacturing process.

The welding industry itself is interested in raising cost efficiency by using simulation tools as much as possible for production optimization and planning.

ABB have taken up the challenge of serving robot arc welding customers by fulfilling these criteria.

The product, VirtualArc®

A unique simulation tool called VirtualArc® has been developed to meet the arc welding requirements of customers. VirtualArc® offers robot programmers, operators and welding engineers an "expert" system providing in-depth analysis of the arc welding process. Its use leads to improvements in process control, final welding quality and productivity.

The simulation tool incorporates state-of-the-art technology, facilitating prediction of the dominant phenomena in the weld. Implementation time and costs for automated processes are saved. The robust software package offers a user-friendly interface, which helps minimize process implementation time and hence reduces the costs of automated arc welding.

Arc welding process simulation technology

The technology behind the VirtualArc® software is based on the combination of arc-physics, a self-consistent two-dimensional wire-arc workpiece simulation tool, practical experience with arc welding and experimental results.

The software consists of different modules that are strongly inter-connected with the whole process system, including power source characteristics and connecting cables. Weld profile and quality predications are obtained using Bayesian neural network technology. Predictions from arc simulations, and heat and mass transfer to the work-piece are used as input to the neural network to predict weld quality and profile as well as defects.

The VirtualArc® software

VirtualArc® consists of different modules with input pages with which the user enters data on the system parameters, the application and the weld process. The first page asks for information on the weld power source, gun, cables and wire feed system. The second asks for the materials, plate thickness, joint configuration, gap, weld geometry and weld class (B, C or D). On the third page details are requested of the wire and gas specifications and whether a short arc, spray arc or rapid arc is to be employed.

Armed with this data, the software then undertakes a pre-weld analysis using a Bayesian neural network tool 1. A further page graphically displays the predictions from the analysis of the weld parameters, the weld profile and the required or default speeds and torch angles. The user can inspect time graphs of current and voltage and a cross section of the weld. The latter shows the depth of weld penetration and profile, enabling the user to assess the quality and knowing the speed, estimate the productivity of the process.

Entering the relevant data literally takes a few minutes. The analysis is completed in seconds. VirtualArc® enables significant time saving by eliminating the need for live weld test runs and the subsequent sectioning of the weld for inspection. In addition to costing time, such live test runs consume components and materials and remove the valuable robots from the production process. VirtualArc® also allows rapid appraisal of "what if" scenarios. In just a few seconds, the effect of different weld speeds and torch angles can be evaluated, making it easier to find ways of improving productivity and/or weld quality. In addition, there are cost and investment pages that enable the user to accurately and rapidly determine expenditure and justify the application before welding is undertaken.

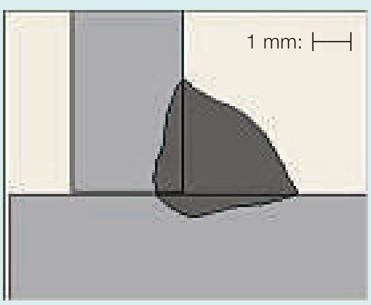
Simulation versus reality

Whenever software replaces testing, the validity of the results is often in question. Comparison of VirtualArc® predictions with test welding data

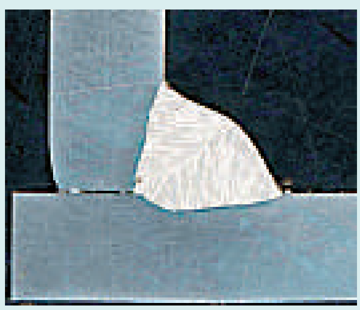
1 VirtualArc pre-weld analysis page.
Analysis is carried out using a Bayesian neural network tool.

2 Simulation versus reality:

Simulated weld profile.



Real weld profile.



shows that the simulated weld profile is extremely close to its real weld counterpart 2.

VirtualArc® benefits

Featuring an easy-to-use software interface, VirtualArc® can be operated from a single PC or laptop. It provides users with efficient "off-line" welding process tuning, which predict a wide range of results including weld shape and penetration, weld quality and possible welding defects.

Predicting such results brings substantial benefits including shorter implementation time, optimised welding productivity and quality, and well documented welding procedures. In turn these considerations contribute to lower production costs' 3.

As well as saving time and money through better production, VirtualArc® is also an efficient training tool for robot operators, programmers and production/welding engineers, and an excellent platform for retrieving and storing arc welding process information for future developments. VirtualArc® is also useful for comparing different weld procedures in cost per metre of weld.

VirtualArc® in use: the example of Andon Automation

Market pressure is forcing welding equipment users to raise their productivity. One way to do this is by making increased use of equipment; around-the-clock production is no exception. Production stops are costly and must be kept to a minimum.

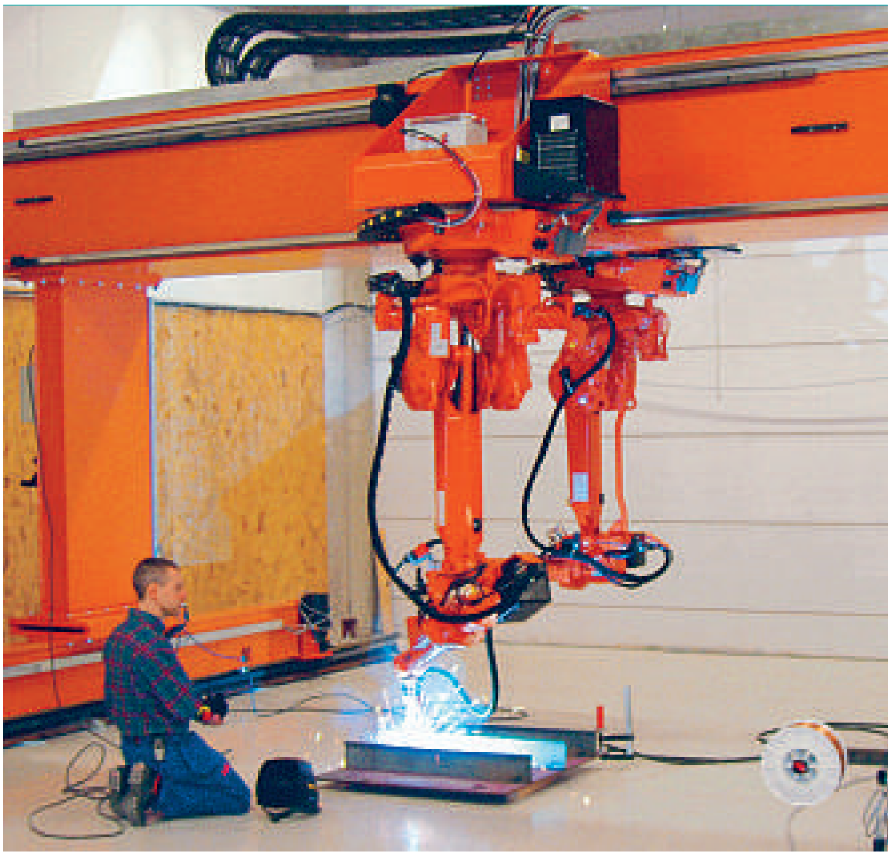
The welding industry is interested in raising cost efficiency by using simulation tools as much as possible for production optimization and planning.

One company that helps manufacturers meet these goals is Andon Automation[1]. Andon Automation not only provides welding customers with hardware (eg, robots, positioners, robot carriers and welding equipment), but also provides support using advanced software tools.

Reference:

[1] See also "Unique and ingenious", pp 23–25.

3 Robot gantry system during testing and before delivery.



Two tools from ABB play an important role here: RobotStudio and VirtualArc®. RobotStudio is used to define and create robot programs offline without requiring any real robots to be diverted from their productive activity, and VirtualArc® is used to evaluate and set welding parameters. Both tools eliminate risk and shorten the production time for new programs while maintaining plant productivity.

Göran Bergling of Andon Automation says that "rom a single PC or laptop we can predict close to exact weld configuration, which results in substantial benefits such as short implementation time, optimised welding productivity and quality – all contributing to lower production costs".

VirtualArc® also facilitates cost and investment analysis, enabling Andon Automation to support their customers by providing financial analyses of production scenarios.

Bergling adds that as a supplier of advanced robot systems, Andon sees RobotStudio and VirtualArc® as excellent tools in the application and implementation phases. On top of this, he predicts that customers will benefit from these technologies in years to come.

VirtualArc® is a tool that enables quality and productivity to be increased and costs to be cut. Customers are given a head start in a competitive and tough market.

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For more information see www.abb.com/robotics

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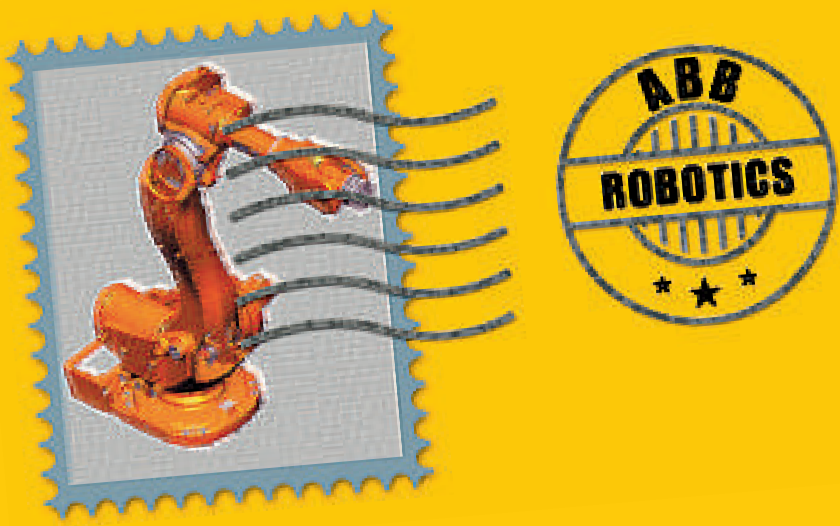
Mail Order

ABB robots are sorting mail for the U.S. Postal Service!

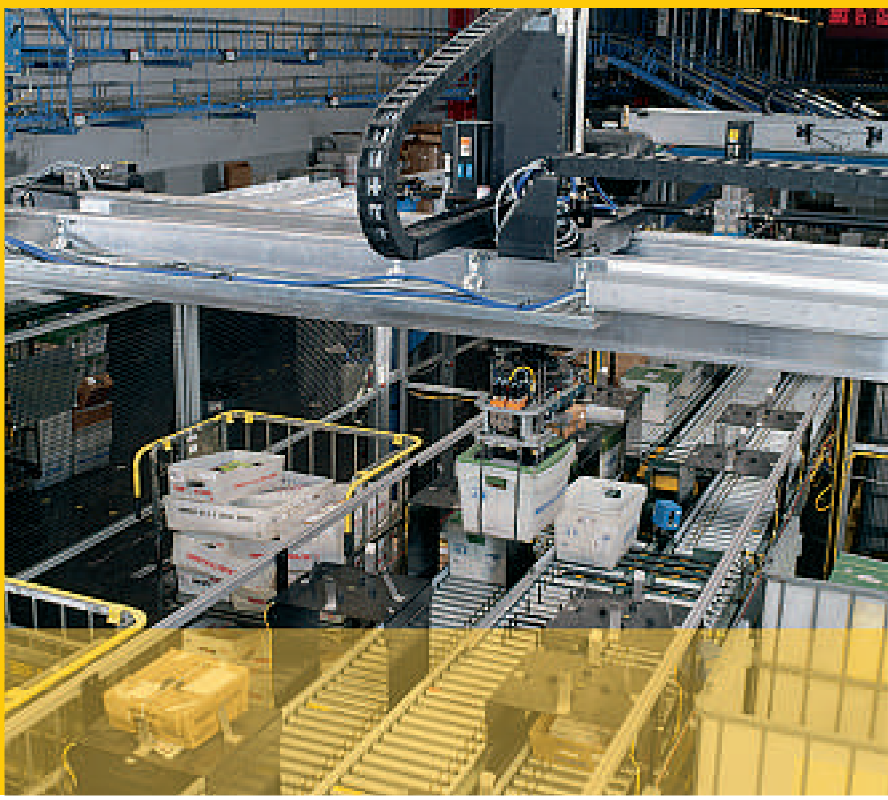
Jerry L. Osborn, Erwin C. Dimalanta



Until the mail service can deliver a letter to you, it has to pass through many hands in many places – increasingly even the hands of robots.

From 1999 to 2001, 100 Robotized Containerization Systems (RCS) from ABB entered service with the U.S. Postal Service (USPS). But, ABB's involvement did not end there. Besides the usual maintenance, training and upgrades, ABB was soon providing more far-reaching services. One installation had to be completely reconditioned following damage in the aftermath of an anthrax attack. Other installations had to be relocated following changes in the deployment plans of the customer.

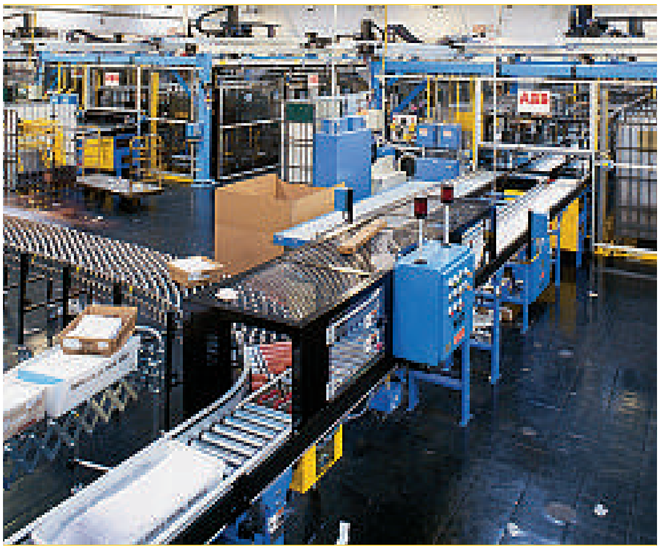
ABB's focus and dedication in completing these planned and unplanned tasks placed them in a good position for winning a follow-on contract. From mid 2005, ABB will deliver 67 systems of a second generation RCS-II.



The story begins in 1999 with the deployment of 100 RCS manufactured by ABB. This project, ABB's first with the USPS, was a major success. The RCS system supplied to the USPS is an automated sorting system for mail trays based on the ABB IRB 840 gantry robot. Two robots are used per RCS installation. The RCS sorts trays of letter mail or magazines (called flats) into 24 postal mail containers. Such operations were previously performed manually. The RCS system was well received by the USPS because it improved the accuracy of the sorting operation (thereby providing significant cost savings), improved productivity, and reduced the potential for lifting related injuries.

Shortly after the deployment of the last production RCS in 2001, the USPS reduced capital spending in automation due to new security concerns brought on by the September 11th terrorist attacks. Throughout the ensuing two and a half years (between the end of RCS-I and the beginning of RCS-II), ABB maintained close contact with the USPS and fostered a collaborative relationship beneficial to both companies. This relationship and dedicated work by ABB staff ultimately resulted in a USPS request for a proposal for 67 additional units – and ultimately the new contract.

ABB Customer Service had been a major contributor to the RCS phase 1 program. The company provided all spare parts support, training development and delivery as well as the man-



ufacture of several RCS components. In early 2002, the USPS requested that ABB Customer Service provide the first in a long list of after-sales support services which ultimately grew to include:

1. Software upgrades to accommodate new USPS bar code configurations.
2. Design of a solution to improve barcode reading accuracy in selected facilities.
3. Numerous maintenance upgrades and services including overhaul of four systems (see below) and relocating of two other systems.
4. Design and production of retrofit kits to improve automatic lubrication of the RCS.

The nature of ABB support was defined in the aftermath of 9/11. Shortly after the terrorist attacks in New York, the US Postal Service was the victim of several anthrax attacks on their facilities. After extensive study, the USPS directed that the facility be decontaminated by an infusion of chlorine dioxide followed by a second infusion of neutralizing chemicals. The chemicals rendered the remaining anthrax spores harmless but at a price – they were very corrosive and caused significant damage to most of the facility equipment including four ABB RCS systems.

In recognition of the good service and reliable performance that ABB RCS was providing, USPS went ahead with the procurement of additional systems from ABB.

ABB was subsequently contracted by the USPS to perform complete overhauls on these systems. ABB technicians dismantled the RCS equipment and replaced or reconditioned damaged components returning the systems to as-new condition.

On another front, the USPS determined that some of the RCS systems were deployed at locations that were not able to fully utilize their productivity. Consequently, the USPS approached ABB to relocate RCS systems from Harrisburg, PA and Toledo, OH to Columbus, OH (to coincide with the new Columbus plant opening) and later from Edison, NJ to the JFK Airmail Facility and from Kearny, NJ to Brooklyn, NY. Relocating these systems provided a valuable service to the USPS.

In recognition of the good service and reliable performance that ABB RCS was providing, USPS went ahead with the procurement of additional systems from ABB.

The RCS-II (as the Phase II system is called) offers an improved computer and software suite, a next generation barcode scanner, and a number of modifications to the deployment and support services tailored to USPS requirements. Production of the first Phase II system is scheduled for March 2005 with delivery of the systems to commence in June 2005 and finish in the Fall of 2006.

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Picking pizza picker

ABB FlexPicker robots demonstrate their speed and agility packing pizzas

Henrik J. Andersson

A good pizza maker is hard to find. He or she has to know how to prepare the dough, how long to let it rise, how to shape it without patting, how to choose the proper accoutrements (tomatoes, mozzarella, etc.) and finally how to cook it, according to tradition, in a wood-burning oven.

While an expert pizzaiolo might prepare a pizza in a few minutes, an industrial pizza machine must turn out hundreds of pizzas in the same time frame. No one would claim that frozen pizza tastes the same as that prepared fresh in a brick oven, but frozen pizza can bring an Italian aura and a good deal of nutrition to people who want the taste of Italy without an authentic pizzeria nearby.

For an industrial pizza producer, making the pizza is only the first part of the problem. It must be frozen, sorted, wrapped and packaged in accordance with regulations for freshness and hygiene, and must not lose its attractiveness during this process. For example, if the pizza starts out round, it should still look round when it arrives in the customer's kitchen. If cheese has been sprinkled on top, it should still be there when the customer opens the package ... and not be left behind on the factory floor.

The challenge

Last year Italian system integrator Vortex, was asked by Panidea, a pizza producer in Italy to design an automated packaging system for frozen pizzas. Pizzas coming from a freezer were to be loaded into a flow-pack machine before going to the cartoning machine. The major challenge was to handle four different products – triangular, circular and oval shaped pizzas. Furthermore, the customer wanted a fully flexible and scaleable system, where new products (new shapes, sizes, types) could be introduced and the capacity increased over time.

A specific challenge with pizzas lies in the fact that they are not collated neatly on the line and may not be perfectly uniform in shape. The pizzas also must be handled delicately with the gripper: there may be cheese or other items on top of the pizza and these can't be lost in the trip from line to the package.

Looking at the requirements of the pizza packaging system, Italian system integrator Vortex Systems concluded that this total flexibility in combination with high capacity could only be achieved with ABB's FlexPicker and its PickMaster software for vision guidance.

The FlexPicker can pick and place while the product is moving on the belt.

The FlexPicker and PickMaster technology

The FlexPicker 1 is a parallel kinematics robot which offers a great combination of speed and flexibility. With picking rates exceeding 120 items per minute, the products can be picked and placed one by one. Since all the motors and gears are fixed on the base of the robot, the mass of the moving arms is limited to a few kg. This means that accelerations above 10g can be achieved.

The FlexPicker has a hygienic design with no painted surfaces. Fulfilling ingress protection norm IP67 it can be washed with low-pressure water and detergents. These features make it ideal for packaging of open food. The fact that the robot is top-mounted means it doesn't restrict access to the robot line, a feature that is appreciated by operators and maintenance personnel.

The FlexPicker is powered by the IRC5 controller (previously by S4Cplus) which allows for conveyor tracking functionality. This means that the FlexPicker can pick and place while the product is moving on the belt. This is necessary in order not to lose valuable time starting and stopping the conveyor.

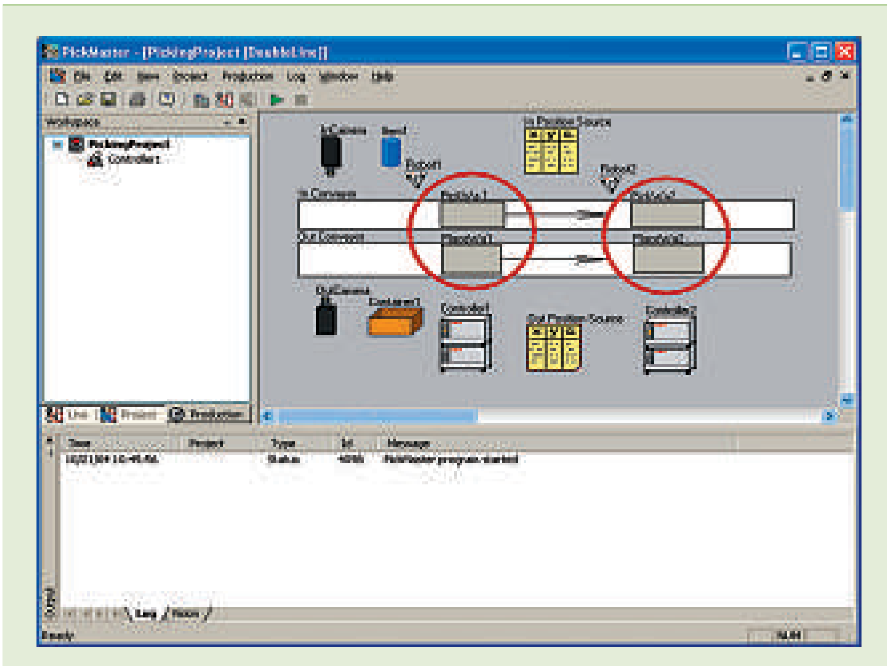
The PickMaster gives eyes to the robots 2. The products are normally arranged randomly on a conveyor belt and the robots need to know their location to pick them up. PickMaster is a PC software package incorporating a Cognex vision system. Furthermore, PickMaster makes the programming of multiple robots (up to eight), cameras and conveyor belts an easy task, even for a not very experienced robot programmer.

The ABB – Vortex partnership

Vortex Systems was founded in 1987. At that time in Italy, robots were used for automotive production lines, not for food. But through a series of encounters, Vortex Systems was confronted with the problem of designing machinery for packaging ice cream

1 The Flexpicker robot achieves accelerations of 10g and handles up to 120 items/minute.

2 The Pickmaster software enables robots to pick items from a moving conveyor with total accuracy.



cones. The opportunity came about by chance, but Vortex Systems devoted itself to the challenge of packaging frozen foods.

Vortex already made its own “robots” but the processing of frozen products requires more manipulation of the product while on the production line. At the same time, these products come in a variety of shapes, and these shapes may change every few months, according to consumer tastes. Vortex engineers decided that for this special application they needed, together with a vision system able to “see” the products coming down the line, a more sophisticated and fast robotic system that has at least four axes of movement to provide sufficient flexibility in their solution.

Vortex decided to enter the frozen food market because they had some new solutions for this industry, despite it being a complex market demanding great flexibility and high hygiene standards.”

In 2003, the company began experimenting with the packaging of frozen products and ABB became involved. In the beginning of the project, ABB made the FlexPicker available to Vortex and supported Vortex with training and support. ABB also provided Vortex a sample robot to work with, learn about and experiment on. Vortex tested and evaluated it and developed several potential applications with innovative features and advantages compared to other solutions on the market

The partnership with ABB and the FlexPicker product has enabled Vortex to compete with much larger German and Swiss competitors. This has contributed to Vortex’s growth and given the company a better presence internationally.

This was the beginning of the very successful partnership between ABB and Vortex, resulting in this pizza-packaging project and other exciting business opportunities. ABB has the robot and the software and Vortex (and the CT group) the experience in building turnkey solutions for the frozen food industry.

The solution

The loading system contains two FlexPicker robots and a PickMaster with one camera each. Should Panidea wish to upgrade the capacity of the system, the layout has room for a third robot at the end of the line. This pizza loading system is the first of its kind in Italy.

A key to the success has been the gripper design. Although single grippers are simpler and cheaper than multi-grippers, the high capacity and product variation makes gripping technology very important. In this project, there are two types of grippers depending on product type. A finger like gripper is used for some formats while others are handled with a faster vacuum gripper.

The flexibility is very valuable to the customer. Since four different products are produced and packaged at the same line, the optimal mix of products can be produced depending on consumer demand.

Each robot has a capacity of 60–80 pizzas per minute depending on the type of gripper being used, vacuum gripper being the faster technology. If a third robot is added to the line, the maximum capacity of the system will be 240 pizza portions per minute.

The cameras and the Cognex vision system locate the pizzas and feed the positions to the robot controller. The products don’t have to be guided or pre-arranged by traditional hard-automation, which would have been very difficult for pizzas. On the contrary, they can be fed on normal flat conveyor belt for all product variants. The FlexPicker robots and vision system take care of the rest. The result is a cleaner robot-based system with less mechanical peripherals 3.

The flexibility is very valuable to the customer. Since four different products are produced and packaged at the same line, the optimal mix of products can be produced depending on consumer demand. The time for change-over between different batches reduces down-time and loss of production, since only the gripper need to be changed valuable production time. Also the system scalability, to be able to add one robot is a valuable option in case of high market demands for the delicious pizzas.

Since the system packages open food, the system is mainly designed in stainless steel according to wash-down standard, a very important requirements in food production.

Customer confidence

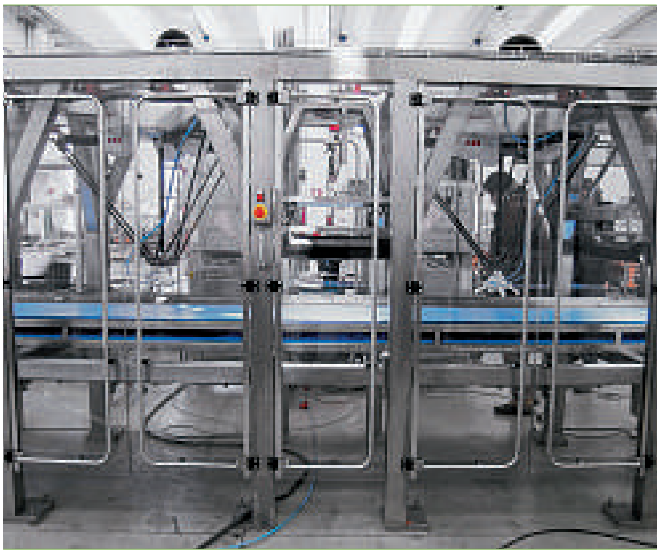
According to personnel at Panidea, the FlexPicker system installation went very smoothly and took some two weeks. The reliability has been very good since the installation in March 2004. According to Panidea engineers, this is probably the only way to automate this application with such a great combination of flexibility and speed. For example, the change of format (to run a different pizza product) can be done very quickly by the operator. The only equally flexible

Vortex Systems

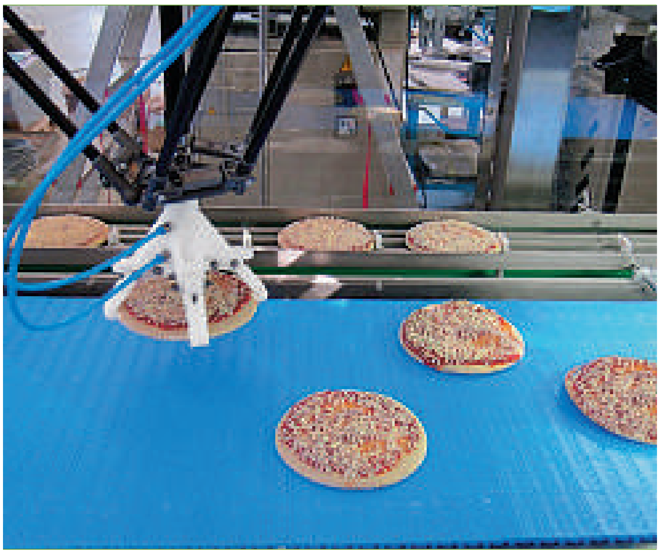
Today Vortex Systems is part of the CT Group. Its sister companies are Catta27: ice cream process, Otem: flowpack machines and Mopa: feeding systems. Together with Vortex, this group represents a global player in providing integrated solutions to different packaging and process needs. Vortex is located in Fossalta, near Ferrara in Northern Italy, where the traditions of machine making are almost as deeply rooted as those of cooking.

3 Picking pizzas from a moving conveyor belt. One wrong move and all the accoutrements are spilt onto the factory floor.

4 The loading system with two FlexPicker robots.



5 The right gripper for a delicate job.



alternative to the FlexPickers, would have been a manual labour based solution.

The Picking Pizza Picker installation is an excellent example of how standard robots and application software result in short pay-back for a food producer. And Panidea plan to continue the expansion of the concept: The future plans for the line is to add one more flow-packer and another FlexPicker to the line 4.

Robots in packaging

During the past ten years, the use of robotics in the area of food packaging increased, and new exciting applications have come up frequently. The standard uses for robots in the food manufacturing environment are in packaging – such as for top loading wrapped articles into cartons, or case-packing, and palletizing, as well as high-speed pick and place applications – and will continue to grow. Robots have become simpler to use, cost less and the technology has evolved to apply to a much wider range of applications today. From decorating machines and extremely reliable quality control functions in the process area, to counter mold feeding into wrappers and mold stacking/retrieval systems, robots are showing up everywhere.

Developments in special end-of-arm-tooling, vision technology and the controller technology expand the things that robots can do 5. Not only has robotics become accepted, but given the real world of operating cost pressures, it's a must that manufacturers at least know enough about what's out there to decide if it makes sense for their needs. If they are not already using some kind of robotics in their factory, they probably ought to be learning all they can about them and looking for opportunities to use them as part of their company's manufacturing strategy.

Those manufacturers, who have been quick to adopt and install new packaging systems, are stealing an edge over their rivals.

Until now, wrapping a new product has been a real challenge for the packaging industry. Whereas humans are able to quickly adapt to pack different products, building robots with the same flexibility is another matter. Until recently, modifying machinery to package different products was too great a challenge. Now, those manufacturers, who have been quick to adopt and install new packaging systems, are stealing an edge over their rivals. This is brought about by specially designed machinery and software developments. Good packaging companies also provide training to make adoption of new technology straightforward and trouble free. Changeover is especially quick and convenient when the entire packaging process comprises one integrated system.

The deployment of robots in packaging lines is an area where technology is quickening the pace and making human hands redundant. Also, unlike humans, robots do not suffer from repetitive strain, fatigue, boredom or any of the related illnesses or conditions these provoke. Establishing the need for robots in packaging lines, however, requires consideration. First, the investment needs to be cost justified, and then the system must be modelled to make the most of the capabilities of robots.

Indeed, robots often replace human workers, which is why their acceptance is often a subject of negotiation. However, robots do present a strong case of their own and this is why we are seeing more and more getting to work in food industry. Incidences of strain industries and lost time in the baking industry are a motivator for many companies to seriously consider the role of the robot. As the USA, UK, and elsewhere in Europe become more litigious, the costs against claims against businesses from workers suffering workplace related injuries will rise.

For more information see www.abb.com/robotics

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Shelf life

The development of the IRB 6650S shelf robot – a successful cooperation between supplier and customer

Ola Svanström

When a customer needs a powerful and agile robot in a very short time and no existing product covers the niche, the chances of success may seem slim. But if the supplier is well-prepared and has a strong modular platform to develop from, then the situation is totally different.

In close cooperation with Gestamp Automocion, ABB was able to develop a new shelf robot in under seven months. The IRB 6650S is handling the customer's tough requirements with ease – these translate into an enlarged working range, an increased handling capacity and a high moment of inertia – all factors which increase the productivity of the customer's lines.

Gestamp Automocion is a specialist in automation of press body shops for automotive industries and a longstanding customer of ABB robots.

In early 2003, Gestamp contacted ABB explaining that they needed improved shelf mounted robots with a better payload and working range.

The time frame for development was very tight but made possible by the recently introduced new large robot platform. This had been launched the previous year and provided a solid basis for further development based on a modular and well thought out concept.

Gestamp – A world-leading supplier of automotive components

Gestamp is an industrial group producing components for the automotive industry such as doors, hoods, panels, covers, supports etc. Most of these parts are manufactured from metal sheets in press shops. The methods used vary, but include press stamping, hydro forming, welding and coating.

The head office of Gestamp is in Spain, with plants located in Mexico, South America and Europe. Gestamp Automocion has more than 7000 employees and a turnover of over 1100 million Euros.

Customers include Peugeot, Citroën, Ford, Mazda, Fiat, Suzuki, GM, Daimler Chrysler, Renault, Nissan and VW-group. For over ten years, Gestamp has been an important customer of ABB robots, and often made important contribution to the development of new robots.

1 A shelf robot's working envelope includes a large area below its pedestal.

2 An IRB 6650S at work at Gestamp's Puebla plant in Mexico.

What is a shelf robot?

The term "shelf robot" is somewhat misleading. It would be more precise to speak of shelf mounted robots; they are designed to be placed on a pedestal or machine at a distance from the floor 1.

Because the robot is placed at a higher "level" than other robots, its working range must extend further down. The robot's working range is tilted forwards and downwards. This is made possible by a different frame (the part of the robot holding the lower arm).

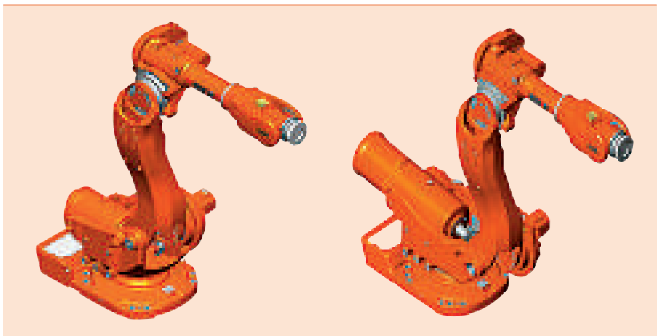
The IRB 6650S features a larger working envelope and a stronger wrist than its competitors. The strong wrist gives the robot a capability to not only handle heavy workpieces, but also to do so with a high moment of inertia. In combination with its high agility, this leads to an exemplary flexibility.

The IRB 6650S is based on the highly modular IRB 6600 family. This means it was possible to develop the new shelf robot to an excellent quality in a very short time. Another advantage of this approach is that options available for the IRB 6600 family will also fit the new shelf robot (service tools will be the same etc).

Joint development between ABB and Gestamp

ABB always appreciates the collaboration of a competent and highly competitive customer when developing

3 The IRB 6650S robot (right) is based closely on the IRB 6650 floor mounted model (left). This use of an existing modular platform made the extremely short development time possible.



4 The press line at Gestamp's Puebla Plant.

new products. The risk of missing certain customer features caused by developing mainly with a single customer is in many cases outweighed by the advantage of not having an over-specified product. In this case Gestamp was an ideal partner as a frontline company in the press tending business.

What Gestamp needed in comparison to previous robot models, was a working range that was much larger in the area below the robot 2, and an increased handling capacity. The high moment of inertia handling ability was especially appreciated.

The biggest challenge during the development of IRB 6650S was obtaining the correct working range and adhering to the time schedule. As mentioned above, one fundamental contribution to keeping the schedule was the highly modular IRB 6600 product platform 3. Although few parts of the robot had to be changed, completely new product characteristics were achieved. In fact, designing the new parts only took about two months.

New concepts for cutting lead-time from suppliers were also needed to meet the Gestamp delivery demands. Design engineers worked in close cooperation with suppliers and their production technology to reduce delivery times. Acceptance test samples were delivered to ABB by airfreight.

To achieve the large working range of the robots, the lower arm needed a new counter-balancing system. A new balancing cylinder with high balancing force and a long stroke was developed.

First installations at Gestamp

The development and delivery of the new shelf-mounted IRB 6650S robot was motivated by Gestamp's aim to run more than 200 references (ie, different press tool geometries) in one press line. This meant that besides cycle time, the production change time, the ability to keep a steady parts flow and the easy access for maintenance and operators were key factors.

For this purpose, Gestamp and ABB Spain jointly developed a standard for Gestamp's lines: The Shelf mounted robots had proven to have advantages over floor-mounted robots for medium and large parts.

In May 2003, representatives of Gestamp including the project leaders for the Gestamp Puebla project development in Mexico 4, agreed to the delivery of the first 8 units of the IRB 6650S for this project.

The very first unit was sent to ABB Spain outside Barcelona just before Christmas 2003 for Gestamp technicians to give ABB their immediate feedback. Gestamp pointed out that the new IRB 6650S had a working envelope below the robot itself like no other robot. This opened up possibilities for tool changing below the robot that had previously not existed.

The other 8 units were shipped in February to May 2004, just in time for the equipping of the new plant in Mexico. The robots worked as Gestamp had expected.

Thanks to the on-time launch of the IRB 6650S robot, ABB has received additional orders from Gestamp for Laser Welding at Puebla in Mexico, for two Gestamp press line systems in Poland and another press line system in Hungary.

Other applications for IRB 6650S

The shelf robots open up new possibilities for the plastics industry. Unloading of injection-moulding machines is one interesting application. Such robots have several advantages over traditional robots for customers:

The cycle time can be reduced because the shelf robot can unload the injection-moulding machine from above instead of from the side. This means the robot has a shorter distance to move, and also that the safety doors of the machine do not have to open and close during every cycle. Less floor space is required for these robots because they can be mounted on top of the injection-moulding machine or on a pedestal beside the machine.

If the robot is placed on a pedestal, the robot and the injection-moulding machine are not mechanically coupled, leading to better process result.

These same benefits are also applicable in die-casting setups. In this case, the robot has better corrosion protection for the harsh environment.

Another application where IRB 6650S has proven its record is in power train assembly in the automotive industry. In this case the robot can replace inverted mounted robots (hanging upside down). Again, the IRB 6650S's advantage is its large working range and lower cost.

For more information see www.abb.com/robotics

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Quick payback for(e)cast

Investing in robotized investment casting ensures quick payback

Claudia Berg

The foundry industry is enjoying steady growth. Investment casting companies are no exception. In this climate, investing in higher productivity has a short payback, as the recent experience of TPC Components of Sweden illustrates.

At TPC Components, the process of manufacturing high quality shells had already been robotised for some years. However, with the introduction of ABB's long-reach, high-payload IRB 7600, it became possible to increase output by an additional 30 %. Ongoing optimization of the installation will improve results even further.

Growth rate in the investment casting business reaches a healthy 6–10 % per year, and customers in the automobile, aerospace, gas turbine, food, medical and process industries are buying more and more components made with the lost wax method.

The method is primarily used for complex and intricate shapes. They are initially formed with wax, which is then coated with ceramic. The wax is melted and drains away (hence the name – lost wax method) leaving a mould into which metals can be poured 1.

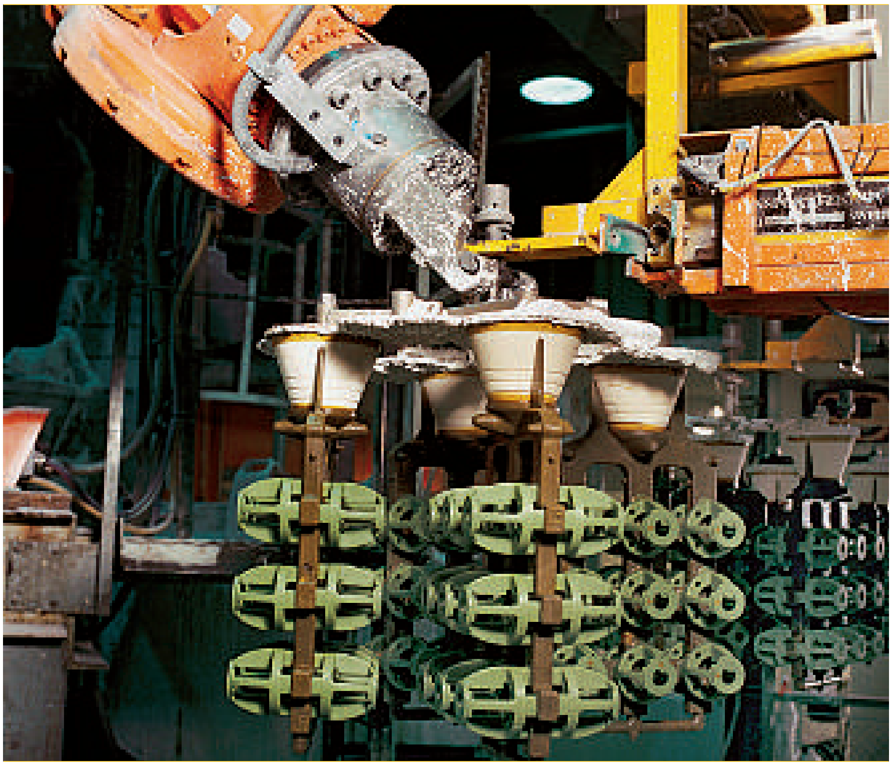
There are a number of reasons why this method has become so popular: It is possible to manufacture complex parts close to their final shape, reducing time-consuming and costly post processing to a minimum. The part can also be produced in a wide variety of materials. The designers can therefore optimise part characteristics. The high precision of the lost wax method results in a very high quality casting with an excellent surface finish.

The high part quality, combined with a large degree of freedom regarding design and material choice, make investment casting an increasingly attractive option.

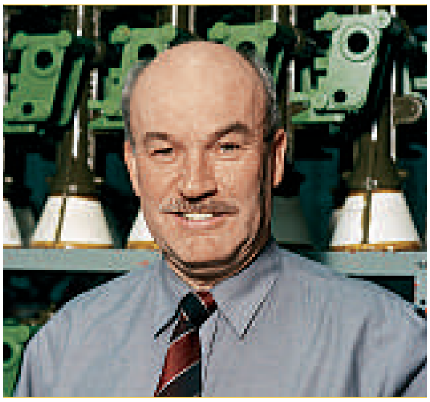
Automation trend

Investment casting is still a labour intensive industry. Production runs are often short, and even large batches require the flexibility and precision of

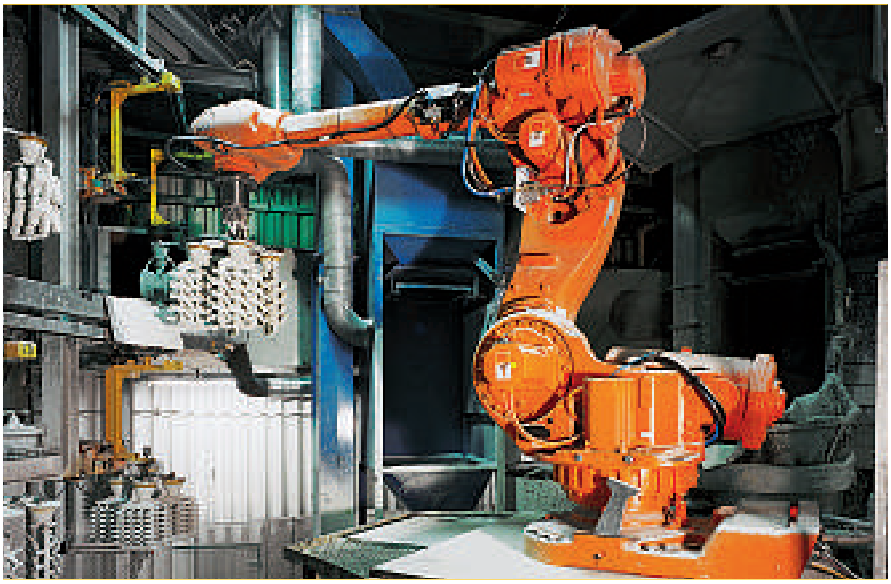
1 Robot arm holding a waxform tree.



2 Bertil Bredin General Manager of TPC Hallstahammar Sweden.

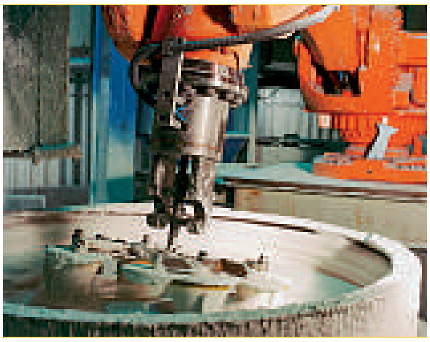


3 Robot IRB 7600 with long arm placing forms for drying.



4 Robot holding form in sand.

5 Robot dipping in liquid.



skilled workers to achieve the high casting quality that customers demand. However, there is a definite automation trend. Shell making, where the wax trees are dipped in an alcohol or water based slurry and where the ceramic shells are continuously built using special sand is often robotised 1. Robots are also used for post processing applications, such as grinding and polishing of the cast part.

Progressive companies are now looking at automating the wax tree mounting area of the shop floor. "Global competition drives us to keep looking for automation possibilities to increase our productivity", says Bertil Bredin, CEO of TPC Components in Hallstahammar, Sweden 2. "Quality control using vision systems is just one example of this trend".

IRB 7600 helps increase output

TPC Components produces some 1000 different articles every year – some in very small, prototype series and others at volumes of up to 250,000 parts per year. The ceramic shell making process is practically completely automated. An old hydraulic Unimate robot previously produced the large shells. Because of its outstanding reach and large handling capacity, it was retained in use for many years. Only recently was it replaced it with ABB's new IRB 7600 long-arm version, which features a reach of 3.5 m and a handling capacity of 150 kg. Thanks to these characteristics, it was possible to introduce the new robot into the existing production line without making any changes to the machinery. Only minor changes of the control system were necessary. The new robot reduces cycle time, allowing the robot cell to handle more parts per unit of time 3.

"The number of manual operations are reduced and final output has so far increased from 1400 trees per day to 1800. When the production cycle is optimised, we plan to produce approximately 2300 trees per day", says Jan Johansson, Manager Shell Department, at TPC Components. When Mr Johansson reaches his goal, the productivity boost will reach almost 65% – an excellent performance by any standard!

It was possible to introduce the new robot into the existing production line without making any changes to the machinery.

Quick payback

ABB's IRB 7600 was selected for a number of reasons. Foremost were the long reach and high payload for which this type of robot is designed. The Foundry plus protection ABB offers with this robot provides IP67 tightness (prevents explosive and alcohol-based slurries from entering the machine) 4.

Both technically and economically, the IRB 7600 is a success.

"Our investment in new automation was basically limited to the robot itself, since we could introduce it without rebuilding the production line. Because of that, pay-back time is not much more than a year and a half," concludes Mr Johansson.

Because of a forward looking management the TPC plant is now well prepared to take advantage of the steady growth the market currently provides. Investing in investment casting clearly has a favourable payback period right now.

For more information on investment casting automation, visit www.abb.com/robotics

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The die is cast

Zinc die caster opts for robot-based automation

David Marshall, Nigel Richardson, Chris Miles

The South Yorkshire based PMS Diecasting is a small but highly dynamic company. It has positioned itself at the forefront of its field by adopting the latest techniques.

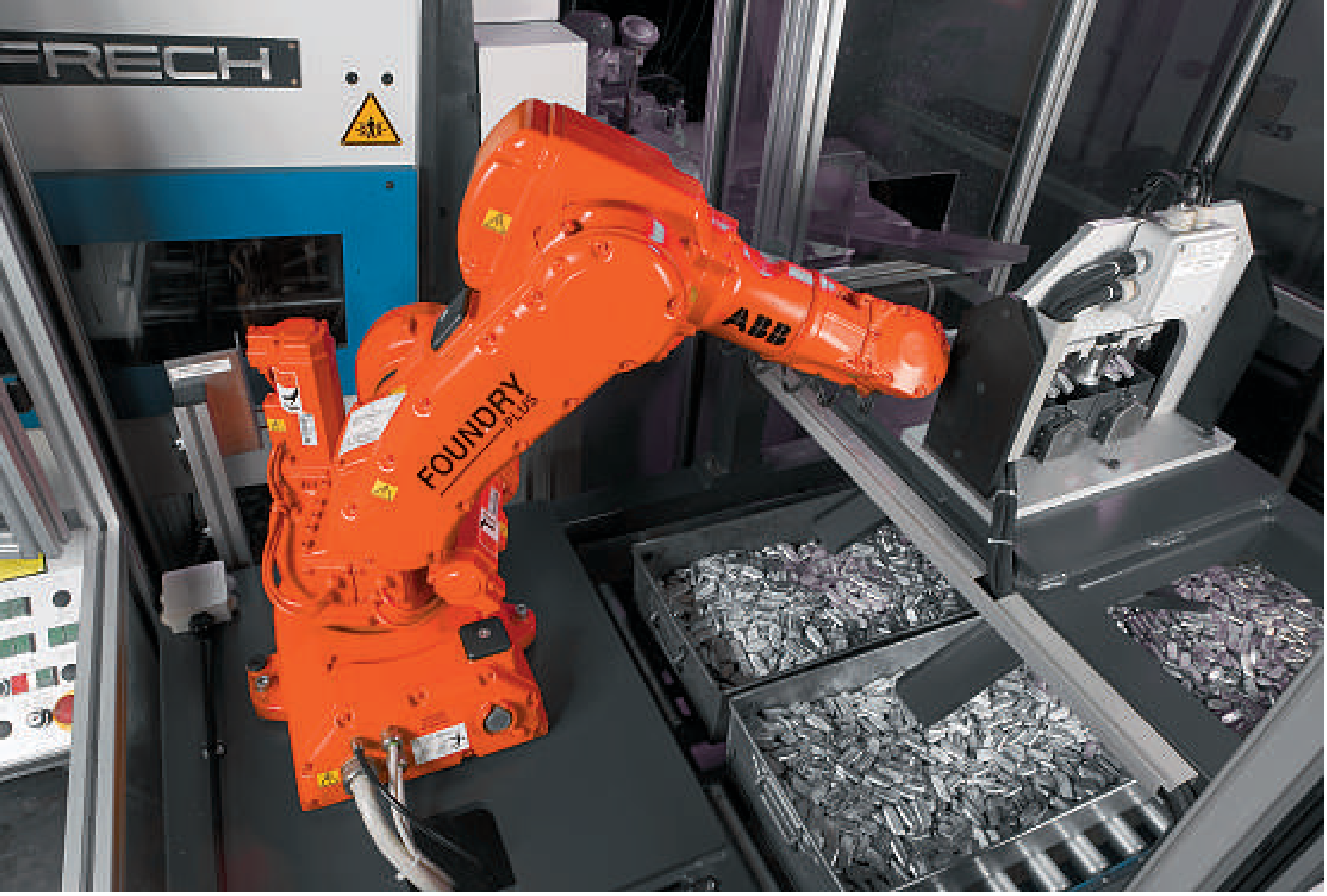
High volume zinc diecasting manufacturer PMS Diecasting, based in Rotherham, South Yorkshire, has automated part of its plant by installing an ABB IRB 140 FoundryPlus six-axis robot, to tend a Frech DAW 20 RC real time control, zinc diecasting machine.

The installation, carried out by robot integration experts Geku Industrial Automation Systems, is unusual in that the ABB robot is tending a relatively small (20 tonne) machine, while the Frech, using real time control (RC), is one of only four such machines operating in the UK.

The cell was the brainchild of PMS Director Gordon Panter, who realised that a fully automated facility could bring significant productivity and cost benefits, particularly when applied to a new contract awarded by wire rope component manufacturer, Sheffield-based Gripple.

The robot cycle is short and relatively simple, with little scope at present for adding extra downstream tasks. The IRB 140 FoundryPlus robot picks up the casting assembly from the Frech diecasting machine using specially designed pneumatic grippers, and transfers it to a part separation station. A pneumatic press then separates individual castings from the runner. The robot directs the runner to a chute for reprocessing before returning to the starting position for the next cycle.

Installed in the summer, the PMS investment appears to be completely justified, with the automated cell increasing manufacturing efficiency and reducing costs. Benefits include: total reliability in a harsh environment; release of skilled manpower; maximised



space; improved quality and accuracy of castings; and a complete "closed loop" for zinc waste.

Plans are in place for Geku to install an automatic feed for zinc ingots, so that a total "lights-out" operation can be established.

Gordon Panter has previous experience in the plastic injection moulding industry, where automated production is commonplace. When he decided to automate, an ABB robot and Frech diecasting machine were the first items on his acquisition list.

"The efficiency of our operation is achieved by eliminating variables, wherever possible. I felt that by buying the most efficient and reliable brands of robot and diecasting machine, a considerable number of variables would be totally eliminated," says Panter.

Having decided on an ABB robot, the IRB 140 FoundryPlus robot was specified after consultation with Nigel Richardson, Joint Managing Director of ABB preferred partner Geku.

The IRB 140 robot is ideal for harsh environments and features full IP67-classified seals, which withstand pressure steam cleaning and liquid impacts up to 25 bar, even complete immersion in water for short periods. In addition, each robot is treated with tough, two-component epoxy coatings to prevent corrosion.

Richardson comments: "As well as operating in a relatively harsh environment, the cell needed to be both space saving and portable, so the IRB 140 FoundryPlus with its compact dimensions was ideal for the PMS operation."

"To achieve portability, we mounted the cell on castors – so it is highly transportable and can be moved away in seconds for access to the Frech for tool changes and servicing. Interfacing the DAW-20 diecasting machine to the IRB 140 robot was also a relatively simple task, as Geku engineers have a wealth of experience with both Frech and ABB systems," he adds.

Commenting on the impact of the Geku/ABB automated cell on PMS Diecasting, Gordon Panter says: "We are a relatively small business and to be highly competitive we must also be highly efficient. This means that every square foot of workspace needs to be utilised and every employee 100 percent effective. To these ends, the Geku-designed cell has had a most significant effect. It is very compact and highly efficient, scrap is reprocessed immediately – rather than being allowed to build up in bulky skips – and an arduous, boring and labour intensive task has been fully automated, allowing staff to use their skills on much more challenging and fulfilling operations."

He adds: "The introduction of full 'lights-out' operation is the next milestone and a significant development for the future success of our business."

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TeachSaver – a time saver

An innovative programming tool opens great new applications for robotics

Per Åström

The foundry-casting process is not always as perfect as many people imagine. Casting leaves excess material known as burrs and flashes and this must be cleaned away before the part can be used as intended. The deburring and de-flashing process is dirty, noisy and hazardous. Additionally, scrap rates are high and quality inconsistent. It might seem that the stage is set for the entry of robots …

Even so, some 80% of foundry cleaning work is still performed manually. The principle barrier to robotization is not the complexity of the task itself, but lies in the programming of the robots. Such programming is time-consuming. With many production batches being small, this leads to excessive down time of the costly equipment. All this is set to change with ABB's new TeachSaver.

This product, an add-in to RobotStudio, brings with it an array of welcome benefits to foundries across the world.

The use of TeachSaver slashes programming time by up to 90%. In addition, it offers better quality products thanks to more accurate calibration and processing methods. Repeatability is a further bonus as well as dramatic timesavings throughout the life cycle of the work cell. And, as programming is carried out off-line, there is never any need to disturb production.

A Time Saver

For decades, the foundry industry has been searching for effective, profitable ways to automate its cleaning operations. The programming time and the fact that the production has to be stopped during the programming is one of the biggest obstacles to a more expansive use of robots and has also restricted automation to only the largest batches. With TeachSaver, robots can be programmed off-line and time cut dramatically – from weeks to hours. This opens up new possibilities for the automated cleaning of smaller batches and complex parts with a high cleaning content.

The use of TeachSaver Step-by-Step

Process path programming

The process path is created with a digital arm or by using a CAD model in RobotStudio. This ensures quick and easy generation of hundreds of robot positions. Guidelines assist the user during programming.

Process path generation, simulation and modification

With TeachSaver it is very easy to generate and simulate process paths, optimize programs, estimate cycle times and eliminate potential collisions. The final result is a robot program that is ready for production – including all customer specific procedures.

Calibration

TeachSaver provides high-accuracy methods for calibration of the tools and of the relation between the robot and the workpiece. This is automatically handled in TeachSaver and the results can be repeated time after time.

Process fine-tune

The process program runs in the robot controller, and if necessary, the positions are fine-tuned. Robot paths are recalcualted automatically according to the changes.

Duplication of cell programs

Duplications of robot programs between robot cells are simple and fast to achieve with TeachSaver. Together with the automatic calibration methods, this ensures identical results in all robot cells; several work cells can be made ready for production in less than a day.

For more information see www.abb.com/robotics

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Reference:
See also "Virtual and real" on pp 62–64.

More colors, less waste

ABB Cartridge Paint System: Cutting Costs and Reducing Environmental Impact

Osamu Yoshida

How many different colors should an automaker offer its customers? A famous pioneer supposedly said, "You can have it in whatever color you want so long as it's black". Today, however, it goes without saying that automakers seek to improve their market position by offering customers as many choices as possible.

But how many choices are possible? Diversity is largely limited by production line logistics. Until now, to change color, the painting apparatus of a robot had to be thoroughly cleaned. This wastes paint and solvent, adds to pollution and costs time and money. All good reasons not to change color more often than is absolutely necessary.

But imagine being able to switch color without losing paint or time, and while reducing solvent waste by more than a factor of ten. With ABB's innovative cartridge bell system, this vision becomes reality.

When a modern car gets into a fender-bender, it's increasingly unlikely that the local body shop will bang the bumper back into shape. Neither will the manufacturer pull a spare out of stock; instead a whole new bumper module will be built specifically to meet the individual need.

This saves on inventory costs, but it makes the paint operations at automakers and their subsidiary suppliers far more complex; not only do they need to paint bumpers for current-model cars, but must also be able to paint small lots of replacement parts for older models.

During the normal production run of a car model, some ten colors are required. For a bumper line, however, that number can often be as high as 50 or 60, and consequently the number of units painted in any one color is limited. Even so, an entire paint line has to be operated to ensure the same quality as the original product.

Whether using hand spray guns or robots, long paint supply lines and atomizers must be thoroughly cleaned with solvent between each paint change. Both paint and solvent are wasted, increasing costs and causing negative impact on the environment (particularly solvents, which contain volatile organic compounds, or VOCs, which are a serious source of pollution). Not the most efficient way to produce bumpers – or any other painted product requiring different paint colors.

The solution came out of an internal brainstorming session. ABB thought that having a traditional paint line with many different paint tanks and all the lines and hoses needed to paint just a few bumpers was a terrible waste not only of paint and solvent, but also of time, labor and money. Why not move the paint tank to the end of the robot arm itself? The total amount of paint needed didn't have to be too much, only 350 to 500 ml, so if a way could be found to put a small tank – a cartridge – on the robot, only the atomizer itself would have to be cleaned with solvent. Each cartridge could be dedicated to one color, so keeping cleaning to a minimum.

As carmakers struggle to position themselves in a highly competitive global market, offering consumers a greater choice in color and features is one way to set themselves apart.

Working closely with a major Japanese automaker, ABB began to pursue the idea – applying it not only to bumpers. As carmakers struggle to position themselves in a highly competitive global market, offering consumers a greater choice in color and features is one way to set themselves apart.

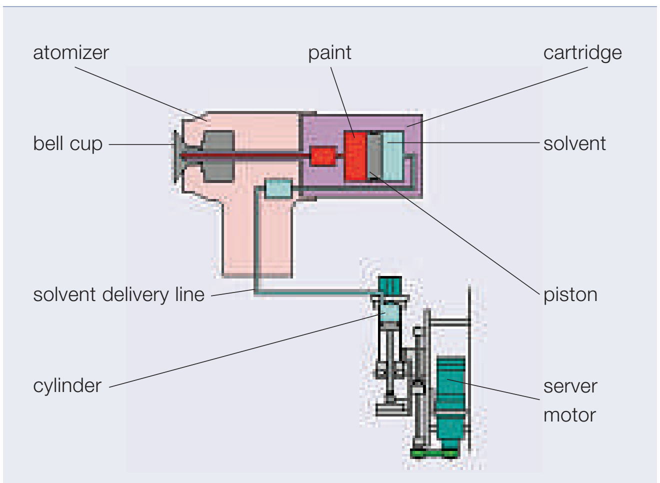
At the same time, the cartridge concept promised to reduce VOC (volatile organic compounds) emissions and paint waste, an important consideration in a time of increased environmental awareness and tighter legislation. ABB thought the concept might also increase the total efficiency of automotive paint operations. They set a number of goals for the project. One was to practically eliminate paint and solvent loss caused by paint change. The other was to reduce material loss at color change from approximately 120 ml of solvent and 32 ml of paint to just 10 ml of solvent: the amount needed to clean the bell cup.

There were several initial technical hurdles that had to be overcome. First was that the time for a cartridge change had to be 10 seconds or less. If this could not be achieved, painting operations would have to slow down – not an option for automakers!

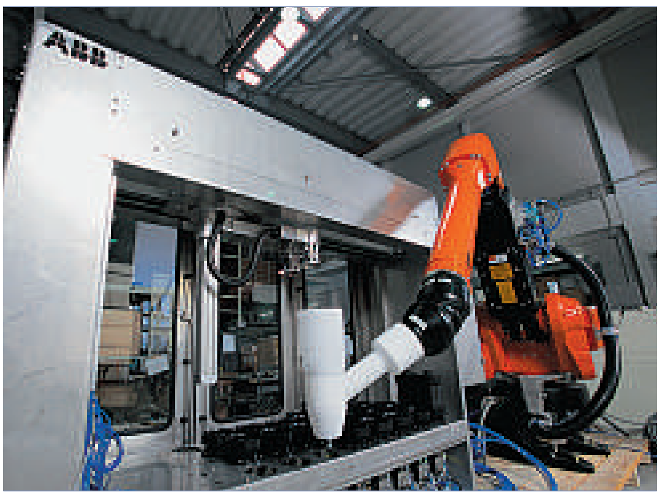
Next was the question of how to hold the cartridge in place in the robot arm. Vacuum pressure was the obvious answer, but it had to be very carefully controlled.

To increase coating efficiency and reduce paint loss, paint robots use electrostatic painting. In traditional hand painting, only a small part of the paint actually adheres to the body – often as little as 20%. ABB is the inventor of, and world leader in electrostatic painting. This technique greatly increases the transfer efficiency of the painting process. A negative electrical charge is applied to the paint droplets as they emerge from the atomizer; the car body has a positive charge. The result is that the paint is not simply sprayed onto the car body, but is ac-

1 ABB's cartridge bell system (CBS). The proximity of the paint to the bell cup minimizes paint and solvent loss when the color is changed.



2 A paint robot changing its cartridge in the manipulator. The empty cartridge is automatically refilled.



tually attracted to it electrically. The major issue raised by this method is sparking. A spark can easily ignite the flammable mixture of vaporized paint and solvent and air. The developers had to find the ideal pressure to hold the cartridge in the robot arm. Too much of a vacuum would have led to sparking.

As these hurdles were cleared, a working concept began to develop. A conventional robot painting systems involves large tanks for the main color, smaller tanks for special colors, a tank for solvent, paint supply lines leading to a Color Change Valve unit (CCV), and a Flushable Gear Pump unit (FGP) mounted on the robot to regulate paint flow. They all have to be cleaned for paint changes. In the new concept 1 the robot was to be separated from the paint delivery system. There would still be paint and solvent tanks, albeit much smaller and for special colors. These would feed to a cartridge handling unit, where the paint would be filled into the cartridges. Each cartridge would contain a piston driven by solvent to force out the paint as painting progressed. A full cartridge would contain only paint below the piston, and no solvent; as solvent was pumped into the cartridge, the paint would be driven out, until the piston was fully extended with only solvent above it. The robot required only a solvent-feeling line; all other lines would be single-usage and lead only to the cartridge station. A surprisingly simple and straightforward idea! At least, as an initial concept.

The cartridge change time requirement made the supply and the removal of solvent in the cartridge an important issue to overcome. What was desired was an almost instantaneous and constant delivery of solvent to the cartridge, resulting in a similarly constant and smooth delivery of paint, with both varying by less than ± 10 ml during the painting operation.

The solution was fairly straightforward, involving the addition of a third valve to the solvent control unit and modifying the shape of the cylinder head inside the cartridge. The result was flow of both solvent and paint from stop to full flow in less than 0.2 seconds, with flow that varied by only ± 3 ml – far below the target figure. This was better than the developer team expected, and it really made the system very attractive for the market.

First realized in the late 1990s, the system – now called the Cartridge Bell System (CBS) – is being applied on automotive production lines not only in Japan, but also in Asia, the US and Europe. As intended, it is a streamlined approach to painting. The exchange unit can be flexibly adjusted with as many colors as needed 2, with two cartridges for each color (one being filled while the second is in use). When a cartridge is empty, the robot arm swings over to pick up a newly filled cartridge 3, set in place by the cartridge handler and held in place by the robot using negative air pressure.

In the meantime, the first cartridge is being filled. The solvent from above the piston is used to prepare fresh paint. When the time for a color change has come, only the atomizer bell is cleaned with solvent; the robot then simply begins to work using a different pair of cartridges.

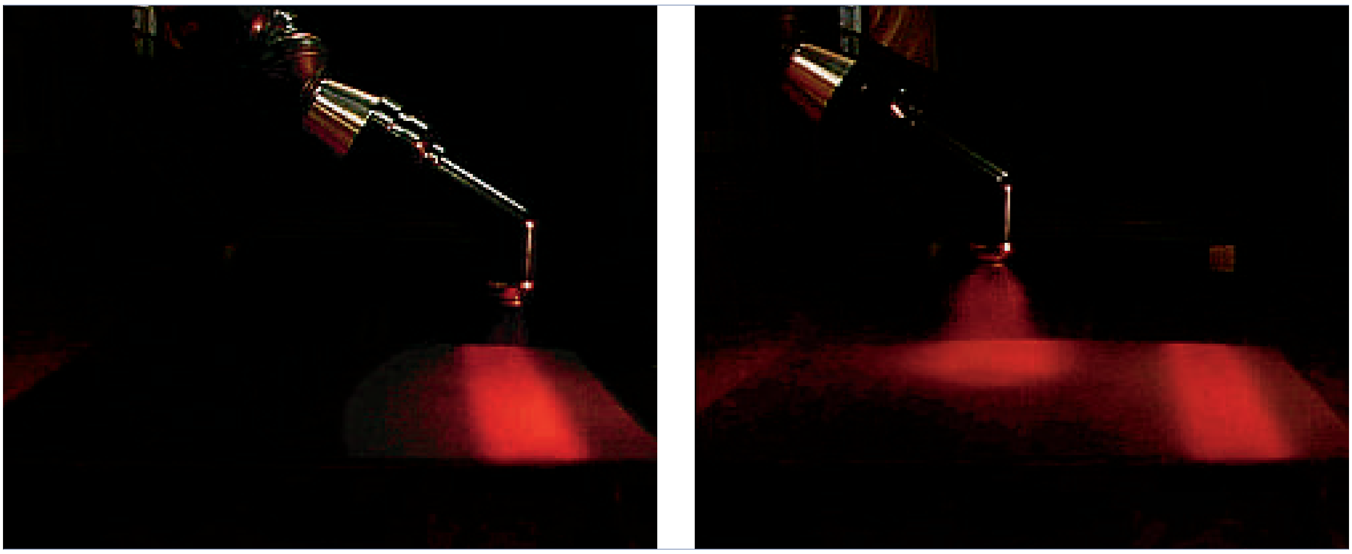
Significantly, this approach leads to safer electrostatic painting, because only the cartridge itself needs to be charged and isolated from ground – no small concern with a charge of 90 kV. Up to 90 % of all the paint is transferred to the automobile body, hugely cutting paint losses. And small-lot paint runs are far easier to handle, and much more efficient and affordable.

The results from a major Japanese automaker speak for themselves:

- A 27-percent reduction in running costs – a savings of ¥3 billion/ US$ 26 million – over the manufacturer's annual production of five million vehicles.
- A 45-percent reduction in VOC emissions during painting, from

3 An ABB technician inspects a CBS installation.

4 The pattern control (PC) bell small (left) and large (right).



65 grams to 35 grams per square meters.
- Improved productivity, with smaller runs of greater numbers of colors, and the possibility of paint-to-order production.

As environmental regulations have become more stringent in recent years, car manufacturers are obliged to switch to waterborne, rather than solvent-borne, paints. Water, naturally, is the ideal solvent, non-polluting and safe to handle. The major problem in the use of waterborne paints comes from the difficulty in utilizing electrostatic painting technologies. Waterborne paints are much more viscous than solvent-based ones, making them harder to vaporize (yet, on the car body, they also tend to remain wet and run more, since water is not as volatile as solvent). Water is also more electrically conductive than solvent. The charged paint supply system must be isolated from the ground, resulting in a system that can be hard to maintain and is potentially dangerous. The result was that electrostatic painting with waterborne paints was impossible for many years.

To cope with this, ABB developed the COPES-IV Bell Atomizer. A bell atomizer has a cup shaped part, the bell, which spins rapidly, flinging the paint off and creating a fine mist that provides superior coating properties. Compressed air spins the bell and shapes the paint mist. ABB engineers succeeded in fitting the COPES-IV with external electrodes that indirectly charge the paint particles, making electrostatic painting with waterborne paints possible. This type of atomizer is now used by European automakers, where stricter EU environmental laws significantly increasing the rate of conversion to waterborne paints.

ABB engineers succeeded in fitting the COPES-IV with external electrodes that indirectly charge the paint particles, making electrostatic painting with waterborne paints possible.

ABB robotic paint solutions are continuously evolving to meet market demands for lower investment, maintenance and operating costs and reduced environmental impact. One variation of the CBS system is the Flushable Cartridge Bell System (FCBS), which provides reduced maintenance costs. Especially when used with waterborne paints, where the problems associated with cleaning by solvent are eliminated, the system allows the cartridge to be cleaned during operations, cutting on routine overhaul of the cartridges. The FCBS has been highly regarded, again particularly in Europe where waterborne paints are rapidly becoming the norm in automobile production. Japanese and Asian auto production has not been as swift to move to waterborne paint, but there are plans to remedy this in the coming years. At the cutting edge of paint transfer technology is the Pattern Control (PC) bell 4. Automobiles and other objects to be painted do not only consist of open, flat surfaces, but have pillars and other smaller surfaces alternating with wider spaces such as hoods and doors. The PC bell allows for on-the-fly changes in paint spray width – narrow on a pillar and broad for the hood, for example – providing outstanding control of the amount of paint being applied. Combined with ABB robots, this is the future of robotized painting guaranteeing maximum transfer efficiency with minimum paint consumption.

ABB Paint Technologies makes it much easier to be a bumper manufacturer – or an automaker, a white-goods manufacturer or any other operation requiring paint color variation and greater response to individual demands – thanks to ABB Paint Technologies.

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Plastics made perfect

ABB robots are revolutionizing the manufacturing of plastics

Christina Bredin

Automobile construction is increasingly evolving away from the all-metal approach. Progress in the manufacturing and processing of plastics makes these new materials suitable for more and more applications previously reserved to metals. Robotics is adapting to this trend – robots are finding increased use in plastics manufacturing.

The following three examples illustrate the success of ABB robots in the automotive parts industry. These robots are employed in tasks as diverse as injection moulding, cutting, gluing and handling. Whatever the application, it is not the cost savings alone that make them attractive, but also the repeatability and precision with which they tirelessly repeat their tasks.

Teaming up with robots

Hemex uses ABB robots to make plastic parts for some of the world's leading carmakers

Mexico's car and auto-parts industries are going through a lean spell. The nation's economy is recovering slowly from a prolonged recession and consumer confidence has yet to gain strength in the United States, to which more than half of the cars made in Mexico are exported.

Yet nobody would guess those difficulties from the smile on the face of Rafael Lopez, technical general manager of the Grupo Hemex plant that makes headlamps at Tlanepantla on the outskirts of Mexico City where a cluster of hills puncture the urban landscape of a capital that is home to nearly 20 million people.

"Production has been growing at about 20% a year, and is continuing to do so," says Lopez as he looks out from his office balcony at the spotless factory floor below. Each worker wears equally spotless white overalls emblazoned with the blue logo of Hella, the Germany-based parent company of Hemex.

The workers form teams of half a dozen or less beneath large signs that proclaim the models for which they are making the parts. The signs are a roll call of auto industry leaders: BMW, General Motors, Volkswagen, Nissan, Mercedes-Benz and others.

And just as soccer squads have a star player, or "libero", who provides a backbone of quality, so too do the Hemex production teams. The Hemex liberos, however, are protected by glass and steel cages, for these are not humans but robots, supplied by ABB Mexico.

Why robots in Mexico? Although Mexican labour costs have risen in recent years, they remain low by the standards of the US and Europe. "That's not the issue," says Lopez. "Each robot costs about $40,000 to $50,000, but we're looking for consistency and quality, and that's what the robots offer."

The robots achieve a precision that no human can match, no matter how skilled she or he is.

"We use the robots to take pieces out of the injection moulder, and for the application of adhesives. The robot's action never varies the way a human's would. That way you get much better quality."

Hence the roll-call of prestige clients that hangs over the Hemex production teams. And, of course, far fewer parts have to be scrapped for failing to meet quality standards. "Besides, with the robots we've achieved a big reduction in downtime," says Lopez.

Productivity is up by about 10 to 20%. But the main reason for getting the robots was the need to improve quality.

Hemex will be investing some $150 million over the next five years. A substantial slice of that is likely to be spent on robots.

In deciding on the purchase it helped that Lopez's boss Eckart Miessner, the Hemex general director, is a former senior executive of ABB Mexico. "In fact, I'm the man who brought the robots to Mexico", says Miessner, who adds that Hemex will be investing some $150 million over the next five years.

A substantial slice of that is likely to be spent on yet more robots to add to the 44 already working at the Tlaneplantla plant. Lopez reckons that about 10 or 12 more will be added over the next two years. Surely the workers must be worried about the prospect of losing their jobs?

"Not at all," says Lopez. "The robots never displace workers. We only introduce them when we launch a new line of production. Since the plant keeps growing and we continue to hire people, fears of job loss are never a problem."

Charlie Chaplin's "Modern Times" film classic posed the comic genius as a factory worker locked in a losing battle with machines. Not so at Hemex. It may be going too far to speak of a love affair, but Lopez emphasises: "The workers get on well with the robots. After all, they save them from the boredom of meticulous but repetitive work."

The plant, founded 30 years ago, has 1,000 workers, with an additional white-collar staff of 500, many of whom perform corporate duties that cover Hemex's other factory, which makes electronic auto-parts in Guadalajara, west-central Mexico. Chief engineer Eric Monroy joined Hemex five and a half years ago, shortly before the first robots arrived. "The plant then was about half the size it is now," he says. "The robots look just the same as they did when they first came." Still a young man, he sighs: "I'm the one who's getting older."

A quest for perfection

Automated and robotized production lines manufacture fabric-covered interior components at Johnson Controls.

At the Johnson Controls plant in Wuppertal, Germany, the pillar trims for the new Opel Astra compact car are manufactured on fully automated, injection-molding production lines. The fabric covering of the trim components is cut using a laser robot supplied by Robot-Technology and an ABB IRB 4400 robot, which is responsible for the ultrasonic trimming process.

The new Opel Astra is characterized by its excellent driving dynamics and progressive design. But the designers of the new generation of Astras were not only concerned with the car's external appearance. Their aim was also to ensure that the interior trim would reinforce the high-quality image of the Opel brand.

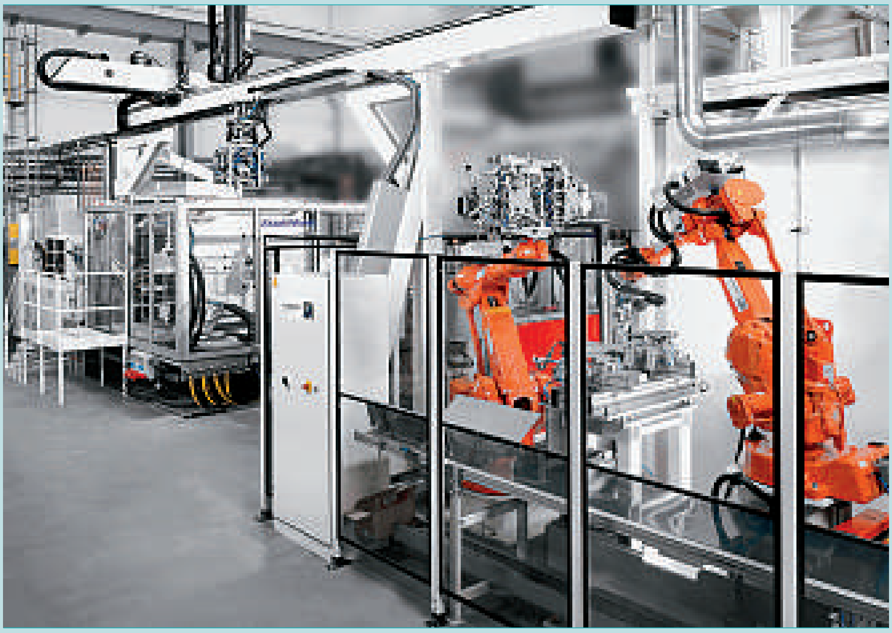
Opel commissioned Johnson Controls, one of the world's leading automotive interiors companies, to design the interior of the car. Johnson Controls developed the entire seating system, the instrument panel, the roof trim and the door and pillar trims for the Astra interior.

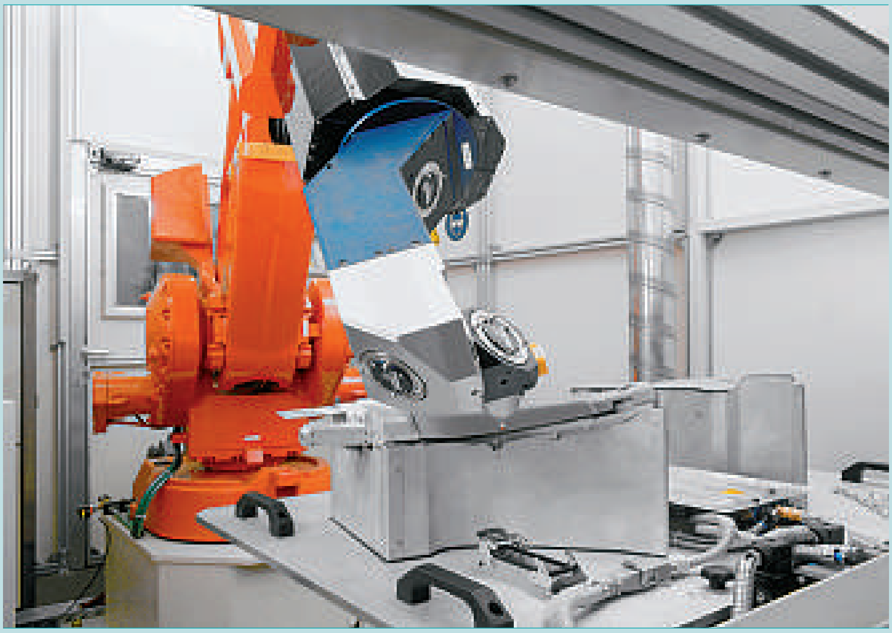
Pillar trims for the new Astra

The pillar trims are injection molded using robot-based production lines. Neureder AG, which specializes in automated systems for manufacturing plastic components, was the general contractor for the construction of the four highly automated, injection-molding production lines, which use an in-mold fabric backing process.

The production lines produce the trim for the A, B and C pillars of the three-door, five-door and estate models. The three lines, which are already in volume production, are identically equipped, with the exception of the A pillar line, which has no laser. The lines consist of an injection-molding machine, a longitudinal pick-and-place robot to load and unload the machine, an enclosed laser cutting cell with a laser robot, a six-axis robot for material handling, another industrial robot for ultrasonic trimming and a conveyor belt to remove the completed trim components and waste fabric. The fourth production line, which will produce pillar-trims for the Astra also has a laser-cutting cell.

Axes 4 and 5 can rotate through 360 degrees. As a result, the components do not have to be rotated or put down during the cutting process





Fully automated in-line process

The injection-molding systems supplied by Krauss-Maffei Kunststofftechnik GmbH have injection-molding machines with the Decoform package use oversize plates for back-injecting the trim components. The production cells use a fully automated in-line process. A linear system from Wittmann, removes the plastic components from the mold and at the same time brings the textile blanks from a rack for the next molding cycle. After removing the trim components from the mold, the pick-and-place robot takes them to the laser-cutting cell and places them on a turntable fixture.

The turntable moves the components into the cell, where they are cut by a Robocut A 300 laser robot developed by Robot-Technology GmbH. The laser robot is based on an ABB IRB 4400 robot. The CO_2 laser has an inherently stable laser housing with axes 4 and 5, which replace the standard main axes of the robot.

Laser robot results in high process speeds

Axes 4 and 5 can rotate through 360 degrees. As a result, the components do not have to be rotated or put down during the cutting process. This which allows them to be cut at a high speed. “The cutting operations follow the pace of the injection-molding cycle,” explains Reiner von Prondzinski, project manager for injection molding at the Wuppertal plant. Other benefits of the laser robot include high levels of component accessibility, high acceleration and an integrated gas-supply process.

The Robocut A 300 cuts the excess fabric off two components at once (the left-hand and right-hand pillar trims are always processed in pairs) and then cuts out the hole for the seat belt, including the slots that will be edge-folded in the following application. “We have divided up the cutting jobs,” says von Prondzinski. “All the visible parts are cut ultrasonically. The invisible parts, which make up the majority of the B and C pillars, are cut with lasers to better fit in with the production cycle.”

Production-ready precision cutting is the decisive factor

Johnson Controls has to meet high processing-quality standards. “The decisive factor is production-ready precision cutting. The cuts on each component must be of consistently high quality,” explains Karsten Spohn, project manager at Robot-Technology. The accuracy of the robots is particularly important in this respect. “The parts are fixed in place. During the laser cutting and the ultrasonic cutting, the robots move the cutting components past the parts," adds von Prondzinski.

Once the laser cutting stage is completed, the parts are removed from the cutting cell and an ABB IRB 4400 robot puts them in an ultrasonic cutting machine. The robot has a multi-grip, permitting it to remove waste material while placing the part on the conveyor belt. In the subsequent production cell, an IRB 4400 with an ultrasonic cutting head cuts and edge-folds the trim components. The robot then removes the finished parts and puts them on the conveyor belt, which transports them to the final assembly area.

High level of automation

The production-line design allowed Johnson Controls to produce ready-assembled parts using a fully automated process in a relatively small area of its Wuppertal plant and to dispatch them with minimal buffering. The in-line process guarantees an optimum throughput time and high cutting quality. According to Krauss-Maffei Kunststofftechnik, the production line has the highest level of automation currently available for this type of application.

A diversity of variants

Flexible robotics help pump out better bumpers – a new order every 90 seconds.

Bumpers have always been an important part of a car's character -– from the earliest motorized carriages through the heavy-metal period to the current era of light, high-durability structural plastics. Riding this trend toward less steel and more plastics, Plastal has grown to become a leading supplier of surface-treated, injection-molded plastic components to the European automotive industry. Its production plant in Gothenburg, Sweden, sequence-delivers bumper systems to Volvo Car's adjacent factory. Every 90 seconds Plastal receives a new set of specifications for a particular car. Eight hours later the completed bumper is delivered – fully painted and ready for mounting.

Plastal's first thermoplastic products were manufactured as early as 1940. Since then the company has evolved into a world-class supplier of exterior and interior modules for both trucks and cars. The factory in Gothenburg's Arendal area – previously internationally recognized as a state-of-the-art shipyard building 100,000 ton super tankers during the 1960s – was opened in 1998 when Volvo began manufacturing its S80 model there. Today, Volvo dominates Arendal, and its models V70, V70XC, S80 and XC90 require a daily production of approximately 2,000 front and rear bumpers. The Production area stretches over 20,000 square meters, has about 300 staff and produces some 400 different models. The bumpers are injection-molded, masked, spray-painted, mounted and sequence-delivered according to a continuously generated schedule provided by an information system.

Every 90 seconds Plastal receives a new set of specifications for a particular car. Eight hours later the completed bumper is delivered – fully painted and ready for mounting.

Plastal presently uses 18 ABB robots, in its Arendal plant 14 of which are paint spray units. At the beginning of 2004, two additional robots were installed in a joint cell supplied by Animex, the plastics automation production specialists. The larger robot serves the injection-molding machine and maneuvers the bumpers into positions that allow the smaller robot to reach and trim off excess plastic.

"Previously we used dedicated single-task fixtures to trim parts after molding," says Emil Arnesson, Plastal's head of molding production technology. "But now, with these more flexible robots, it's easy to implement program changes when a model is altered or a new version is introduced. Plastal saves both time and money, compared to buying a brand new trimming fixture. Together with Animex, they have created a team that ensures smooth handling of new versions as they appear. This allows Plastal to maintain top levels of competence and competitiveness."

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Offline programming, online productivity

The offline programming tool RobotStudio is a worldwide success

Karin Dunberg

ABB first launched RobotStudio in 1998. The offline programming software rapidly spread across the world, helping increase productivity and cut costs in a diverse range of industries.

RobotStudio allows robots to be programmed on a PC in the office. Robot programs can be prepared in advance, increasing overall productivity by performing tasks such as training, programming, and optimization without disturbing production [1].

ABB asserts that RobotStudio is the ideal software for producing and optimizing robot programs off-line. The proficiency and elegance of this software is witnessed by the following customer reports:

Volvo Construction Equipment (VCE) Cabs AB – Sweden
Volvo Construction Equipment (VCE) Cabs AB is one of the world's leading manufacturers of construction machinery. The company is now reaping the benefits of using RobotStudio and its peripherals. VCE produces cabs for construction machines, hydraulic and fuel tanks, car bodies and hydraulic cylinders. For Anders Nilsson 1, robot-welding technician at VCE Cabs, the picture is clear:

"Time-consuming online programming leads to long and costly production stops which we simply cannot afford. Offline programming of a weld is about 20% faster than programming the weld online. This may sound like a marginal saving, but considering what a production hour in a weld cell costs, the investment is recovered after the first project."

Anders is an offline-programming veteran. "We have been working with offline programming since 1995. RobotStudio is used to program welds on cabs. The robot then carries out the weld stages on the tack-welded original".

With the RobotStudio application for welding, RobotStudio ArcWeld PowerPac, Anders can control gun angles, tilt and seam positions with great precision.

"RobotStudio runs on ABB's own control system. This means that when I have produced a program that functions in RobotStudio, I can know with 100% certainty that it will function in reality".

Crenlo, LCC – USA
Across the North Atlantic in Minnesota, Crenlo, an expanding specialist manufacturer of rollover protection cabs for off-road construction equipment, was able to program its robots even before its new plant had been completed!

The race began with a contract to manufacture rollover protection cabs (ROP's) for Caterpillar. With both of Crenlo plants in Minnesota at full capacity, it was decided to install a new line at the planned plant in Florence, South Carolina. Jeff Peterson 2, Crenlo's robot applications supervisor, understood that waiting for the factory to be completed to then program the robots online – and then adjust peripheral equipment at each work station – was a handicap the company could ill afford.

RobotStudio enabled Peterson to not only program the robots off-line but also plan the set-up and production flow before the workstations were even built. In fact, RobotStudio slashed setup time by 75% compared to manual programming.

Robot programs can be prepared in advance, increasing overall productivity by performing tasks such as training, programming, and optimization without disturbing production

"Thanks to the fact that RobotStudio employs the VirtualRobot™ Technology, incorporating the controller software from the real robot, there's really no risk of error in this type of situation because you're running exactly the same machine offline in the office as online on the shop floor", assures Jeff.

Polynorm – Holland
Polynorm in Holland is a leading tier 1 supplier to the automotive industry. Polynorm's main activities are the pressing, assembly and coating of bodywork components such as panels, doors and hoods, both for line assembly and after-market service.

Polynorm supplies a wide range of spare parts to the automotive industry. The company has an impressive production line with 92 robots and is continuously increasing this number. With RobotStudio they can switch to a new product faster because they prepare the programs in advance and test them offline. This makes them much more flexible.

"Previously, we had to build one unique robot cell for every new car model to be able to meet our customers' requirements. That was expensive and inflexible. Every time we changed models or parts we had to build up an entire new cell", explains Mario Smink 3, Manager of the Equipment and Infrastructure Design Department.

"We wanted to move forward to stay ahead of the competition. With offline programming we saw an opportunity to reduce production costs".

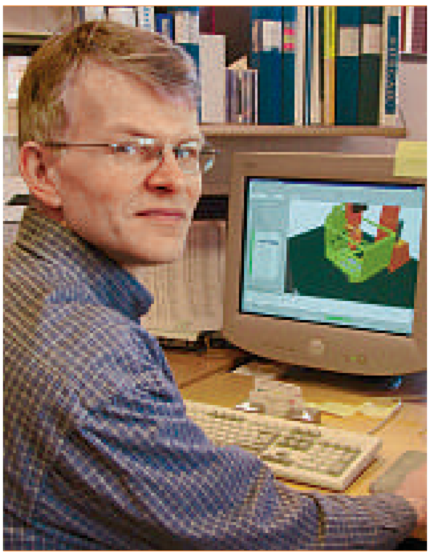
Before the investment, Polynorm evaluated robotics products from around the globe. For offline programming, three systems were tested: RobotStudio, Igrip and Robcad. The result of the study showed that RobotStudio was the best offline-programming tool for Polynorm.

"One of the reasons for picking RobotStudio is that it's designed for robot programmers and not for CAD designers. Another important feature is that the verification is incorporated in RobotStudio, and that is very user-friendly. RobotStudio is a praiseworthy product that can be installed on a standard computer", establishes Mario Smink.

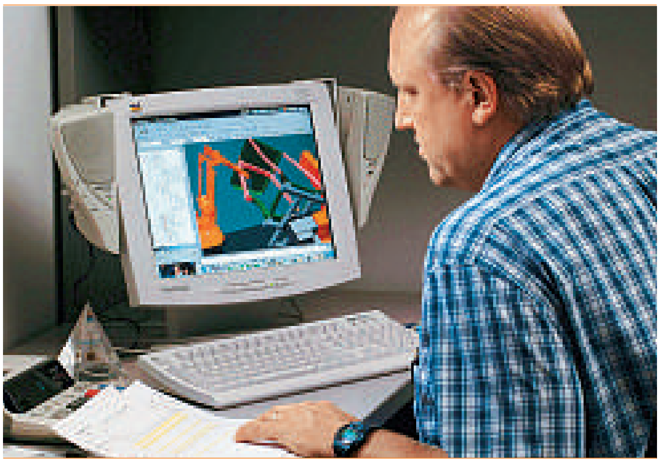
Polynorm is a cost-minded company and bases all its investments on payback time calculations. In the case of RobotStudio, payback was less than six months.

"Productivity has risen enormously since we started to program offline. We have reduced the commissioning time for new products by 90%. This represents a huge improvement in productivity and the utilization of assembly cells. The investment in RobotStudio was really worth the money", concludes Mario Smink.

1 Anders Nilsson of VCE (Sweden) manufactures construction equipment: The investment in software was recovered after the first project.



2 Jeff Peterson of Crenlo (USA) makes rollover protection cabs: The robots could be programmed before the factory was completed.



3 Mario Smink of Polynorm (Holland) supplys bodywork components to the car industry: RobotStudio helped reduce commissioning time for new products by 90 %.

Foxconn – China

Foxconn, with its more than 80,000 employees, is the biggest industry in China. The Shenzhen plant in the south of China manufactures enclosures, primarily for desktop PCs and PC servers. The plant's prestigious customers include Dell, Apple, HP, Cisco, Symaco and Nokia.

"Our management strategy is time to market, time to volume and time to money. With RobotStudio, we can reduce evaluation time and shorten development cycles. This helps us achieve our strategic goal and satisfy our customers", explains Yuan Xiao Yun 4, responsible for research and study of automated technology applications at Foxconn Network System Group.

4 Yuan Xiao Yun of Foxconn (China) produces enclosures for desktop PCs and servers: Saving time is the key to survival in a business of tight schedules and tough deadlines.

Foxconn started using ABB robots in 2000. Today there are about 110 ABB robots at the Shenzhen plant. Initially all robots had to be programmed online, requiring a lot of re-positioning. Foxconn recognized the productivity potential of offline programming.

RobotStudio has changed workflow and improved productivity. Production time has been cut down, especially when introducing new products.

Since the introduction of RobotStudio Foxconn doesn't have to process onsite debugging and programming when introducing new products to their production line. Now they simulate and debug the production process, optimize the programming path and reduce cycle time in RobotStudio before starting production. This has changed workflow and improved productivity. Production time has been cut down, especially when introducing new products. "With RobotStudio, new products are introduced on time. This is essential for survival in this business", says Yuan Xiao Yun, giving an example:

"One of our clients needed to mass-manufacture a product in a very short time. His requirements put us under a lot of pressure. With RobotStudio we could shorten our programming time and thereby achieve our client's productivity goals, enabling him to meet his market deadlines."

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References:
See "Virtual and real" on pp 62–64.

Team-mates

ABB MultiMove functionality heralds a new era in robot applications

Christina Bredin

There is more to robot coordination than avoiding collisions. Operators wish for more precise synchronisation so that robots can team up to complete tasks that are beyond the capability of a single robot. Two robots could, for example, lift an object that is too heavy or too bendy for a single unit. Or a group of robots could simultaneously work on an object while it is moving or rotating.

Such tasks require a very high degree of synchronisation. ABB's new IRC5 controller makes this possible, permitting robot groups to handle more complex tasks than ever before.

The technology step taken by ABB in the development of its fifth generation robot controller, the modular IRC5[1], is one of the biggest since the launch of its first generation S1 in 1974 and the IRB6 – the world's first electric drive robot. Of the advances made with the IRC5, it is perhaps the introduction of *MultiMove* that will have the biggest impact in terms of applications and customer benefits.

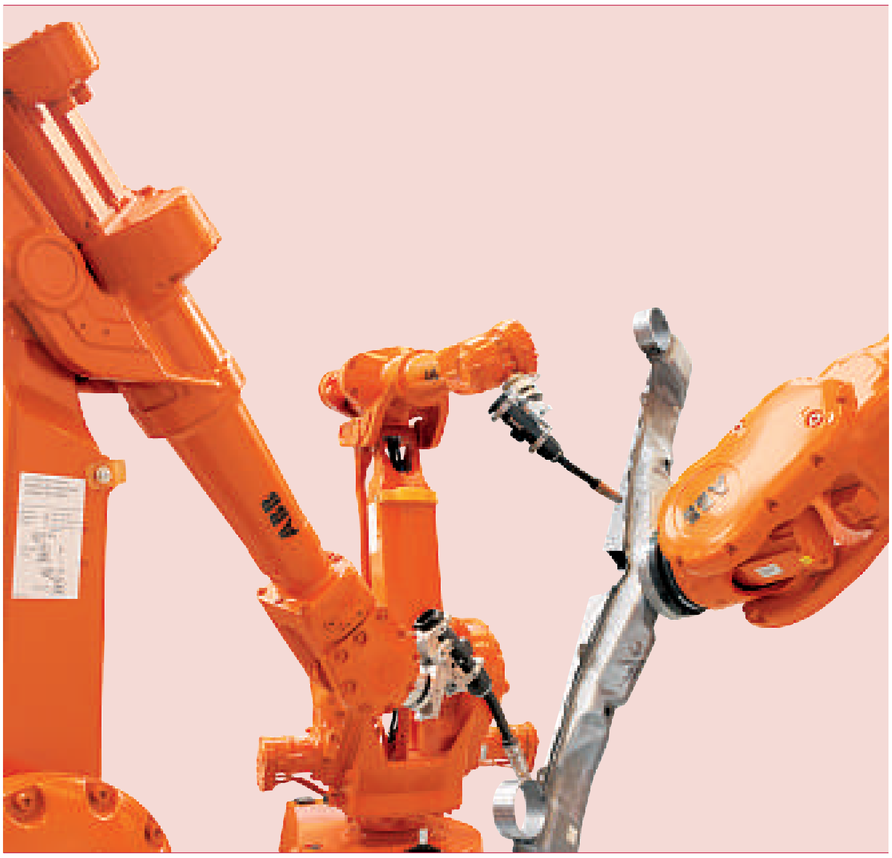
MultiMove is a function embedded into the IRC5 software that allows up to four robots and their work-positioners or other devices to work in full coordination. This advanced functionality has been made possible by the processing power and modularity of the IRC5 control module that is capable of calculating the paths of up to 36 servo axes.

Such power, however, does not inflate cost as the modular concept of the IRC5 permits a lean solution. Irrespective of whether the cell has single or multiple robots, only one control module is required. Expansion only requires the addition of a drive module per robot up to a maximum of four. This approach significantly reduces the requirement for communication links compared to the more common multiple controller solution.

MultiMove is a function embedded into the IRC5 software that allows up to four robots and their work-positioners or other devices to work in full coordination.

The principle of MultiMove is an expansion of that used in coordinating a robot with a work-positioner, but this older technology can coordinate only two robots or other devices. With MultiMove, the work-handling device, which can be a robot or work-positioner, controls the work object. The other devices are coordinated to move relative to the work object. This is achieved by defining the object coordinate systems of each of the coordinating devices as relative to the work-object held in the handling device. When the work-object moves, the other devices move in symphony.

1 The MultiMove function, which is embedded into the IRC5 software, allows up to four robots and their work-positioners or other devices to work in full coordination.



Even though MultiMove is a complex function to implement and requires large processing power (particularly in the path planning and synchronisation of the drive motors of all robots), its operation has been kept simple. Feedback from customers given early exposure to MultiMove has indicated that anyone familiar with programming an ABB robot, particularly when coordinated with additional axes such as a work-positioner, should have little difficulty in creating MultiMove applications.

A key to the easy implementation of MultiMove is that each robot or additional device in the cell has its own program. This may be written and edited in ABB's RAPID robot programming language. Each program may be viewed and executed totally or partly independently of other programs using either the Windows style FlexPendant graphical teaching unit, which has been developed as an integral part of the IRC5 controller, or a PC. This concept of program separation in the MultiMove function is unique to ABB.

MultiMove is totally flexible because of its ability to switch between coordinated and independent operation of the robots in the cell. For instance, all the devices can operate totally independently of each other all the time; or they can be synchronised at certain points in their cycles (semi-coordinated movement); or they may work in coordination with fully synchronised sequences and movements. Furthermore, the robots can operate in groups with two or three coordinated, while the other robots in the cell work independently.

In semi-coordinated operation, the robots in the cell work on the same stationary object. This requires some time synchronisation in the sequence of operations but not any coordinated

Reference:

[1] www.abb.com/robotcontroller

movements. For example, a positioner moves the work-object while the robots wait, and the robots only work on the object while it is stationary. This semi-coordinated movement requires synchronisation only to "advise" the positioner when the workpiece should be moved and when the robots can work.

An example of this is two robots welding the same workpiece in different areas and on two different sides. The positioner first moves the workpiece to present its upper side. Then the robots perform their welds while the positioner waits. Next, the positioner rotates the work. Finally, the robots perform their welds on the lower side.

In fully coordinated movement, several robots operate on the same moving object 1. The positioner or robot holding the work and the robots operating on that work, move in synchrony. Therefore, the coordinated robots must start and stop their movements at the same time and must execute the same number of move instructions.

An example of fully coordinated movement is a spot welding task in which the work is continually moved along an arc by one robot while two spots are applied by a weld gun held by another robot that is coordinated with the first robot. A single instruction in the work handling robot's program is sufficient to move it from the start to the finish of its trajectory along the arc. However, because the welding robot applies two spots in different spatial positions and, therefore, requires two instructions in its program, the handling robot must also have two instructions. Therefore, the arc movement must be accomplished using two move instructions, one to a midpoint and another to the end of the arc, which are executed synchronously with the two move instructions in the welding robot program.

Shorter lead times, increased productivity and improved quality are some of the generalised potential benefits of multiple robot operation with the new IRC5 controller.

Another feature of MultiMove is the ability to jog multiple robots using the joystick on the FlexPendant 2. During "coordinated jogging", the relative positions of all the devices remain constant and are exactly the same as during the full speed execution. At any point, any of the devices can be switched to an independent jog so that their relative position may be adjusted and then switched back again for the coordinated jogging to continue. This is a powerful tool in fine-tuning MultiMove programs and is only offered by ABB.

Recovery from a production stop due to equipment or process failure is a potential problem due to the complexity of the choreography in MultiMove operations. Not only has the robot at "fault" to avoid work and tooling, but it must also coordinate with its "partners" during its retraction to a safe position as well as on returning to its last position. The problem is eased by the IRC5 controller because of its path recording functionality. This is activated for every robot in a MultiMove operation. Knowing the path leading to the error point enables the faulty robot to retract in synchrony with the coordinated robots to a safe point that is identified in its RAPID error recovery routine. The same path data will similarly be used after recovery to return all the coordinated robots to the program positions at which the error occurred.

Some errors necessitate the re-execution of a command (otherwise known as a "retry") rather than returning the robot to its last known position. An example of this is an arc failure during arc welding. In this case an arc

2 ABB's Flexpendant (left) is part of the IRC5 package. It supports robot programmers (right) through its ergonomic design, customized menus and touch screen.

3 The "brain" of a synchronised robot cell is the IRC5 controller.

restrike makes more sense than a retraction. Therefore, a "retry" will be specified in the RAPID error recovery routine. In MultiMove all devices need to be coordinated during the retry.

To make it easier to recover from such errors in arc welding, ABB has developed a new *"asynchronously raised error"* function in RAPID. For instance, in the above example it is most likely that the arc failure will occur along the programmed path after the instruction has been executed but before the robot has completed its movement to the end of the path. In this case, it is necessary that the error recovery routine is executed at the point of the arc failure and not at the completion of the instruction. The asynchronously raised error function allows this to occur in MultiMove as well as in single robot routines.

Shorter lead times, increased productivity and improved quality are just some of the generalised potential benefits of multiple robot operation with the new IRC5 controller 3. Even in totally independent robot operations, time and costs are reduced due to the efficient internal communications and minimal handshaking of the single controller. When some degree of synchronisation is introduced, waiting times can be minimised leading to further reductions in cycle times.

Better product quality is a high potential benefit of MultiMove. This can be achieved, for example, with two or more robots working together in order to balance the load on the workpiece. An illustration of this is simultaneous arc welding to eliminate the risk of distortion due to uneven shrinkage on cooling. Another is the use of two or more robots to handle delicate or flimsy workpieces that may flex or bend under their own weight.
It is also possible to expand the "part-on" concept with MultiMove by coordinating a workpiece-handling robot with one or more process robots, helping to simplify and reduce tooling and fixturing. This can also reduce cycle time as the time to place the workpiece in the fixture has been eliminated and the process robots may be able to start their operations as soon as the part is picked up. Moreover, the 6-axis robot has more dexterity in manipulating the workpiece as compared to a rigid fixture or even a servo-controlled positioner. This could mean, for instance, that the process robots are able to access all areas of the work, allowing the operation to be completed in one handling with no intermediate stops for reorienting the work. This is called one-stop or one hit processing.

Another advantage of coordinating a work-handling robot with two or more processing robots is the higher relative speeds attainable, for instance, between the weld torch and the workpiece, leading to possibly better quality welds and/or shorter cycle times. A further benefit is in lifting heavy loads. It may be less costly to employ two smaller robots to lift the load rather than a larger one, or the load may be heavier than the capacity of the largest robot but not of two robots working together.

The unique functionality that MultiMove brings to the whole ABB robot range sets new standards in robot technology and opens up a range of applications that were previously impractical or uneconomic. Its development has been backed-up by the knowledge gained from the previous four generations of ABB robot controllers and aided by the expertise generated from over 125,000 ABB robots installed worldwide. MultiMove further strengthens ABB's lead in advanced robot systems.

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For more information see www.abb.com/robotics

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Welding double

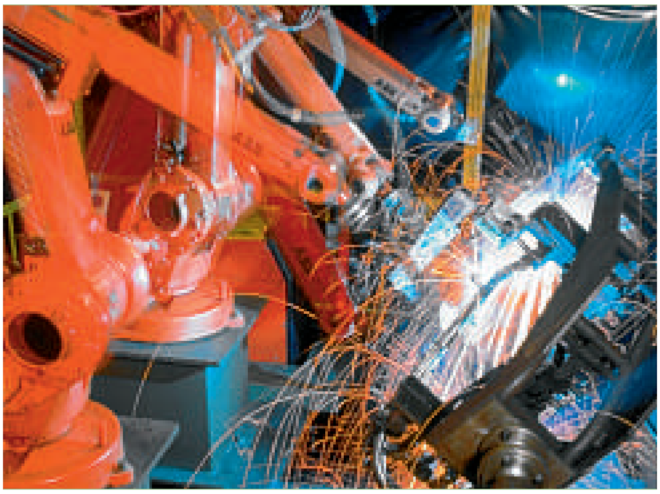
MultiArc – the perfect welding team

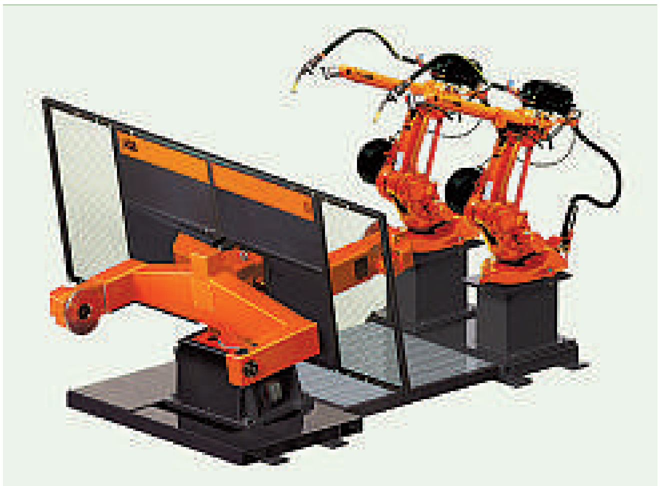
Sofie Kallgren

There are many reasons for coordinating welding robots. Two robots working simultaneously on the same workpiece save time and space. But besides producing more for less, robot coordination is also about quality. For example if a seam is welded from both sides simultaneously it will cool more evenly leading to a better join.

The obstacle has long been mastering the precise coordination required. This is even more an issue where besides the two welding robots, a positioner must also be integrated in the coordination. ABB's new IRC5 robot controller simplifies all of this. The controller provides perfect coordination and is, at the same time, no more difficult to program than a single robot. Suddenly, teamwork in robot welding is a graspable reality.

MultiRobot section





MultiArc is a new concept for arc welding where more than one welding robot can be coordinated with a single positioner using ABB's new IRC5 controller. The combination of a brilliant brain and diligent hands makes MultiArc the perfect combination for arc welding.

MultiArc was developed by arc welding specialists in close co-operation with experienced and demanding customers in the car industry.

The new robot controller, IRC5, can integrate up to four robots. For most industrial arc welding applications, however, the optimal solution is a combination of two robots working with one positioner. Two welding processes active simultaneously on the same positioner lead to superior accuracy, increased quality, shorter cycle times and reduced floor space.

Advanced welding process know-how

MultiArc was developed in close co-operation with experienced and demanding customers in the automotive industry. Based on deep and advanced arc welding process know-how, MultiArc is a mirror in which operators and welding engineers will recognize their skills. They will also recognize the ease of use, high up-time, versatility and flexibility that are distinctive features of ABB robotics products.

MultiArc – a concept for different needs

Big or small – but always fast! To meet a wide range of different customer requirements, MultiArc standard configurations include two IRB 140, 1400 or 2400 robots combined with one IRBP positioner, type R, K, D or L.

These standard configurations cover the majority of industrial arc welding applications but they do not exclude the possibility of non-standard combinations; solutions can be tailored to individual customer needs. Different robot types can be integrated, including for example, one for material handling.

The MultiArc features and benefits

- One controller co-coordinating two welding processes means powerful motion control and the elimination of synchronization times; this, together with superior path accuracy and perfect repetition, leads to shorter cycle times.
- Two simultaneous welding processes result in better and more even heat distribution. This minimizes the risk of deformation or cracking, thus safeguarding quality.
- Two welding processes on the same positioner mean reduced floor space, increased flexibility and lower fixed production costs.
- Using two integrated welding processes is about 70 % more efficient than a single robot solution which means a substantial increase in production output.

ABB's paramount principle for robot welding is to get the best possible weld at the lowest possible cost. Designed on the basis of using the optimal combination of proven components to obtain an efficient and flexible product, the new MultiArc concept is ideal for handling a wide range of complex parts.

MultiArc – ABB sets a new standard

Multi-robot solutions are becoming more and more common. ABB has made these systems simpler to use. Programming is as easy as for a single robot system, so reducing programming time significantly. MultiArc welding cells are built from ABB standard components, ensuring reliability and a long life. ABB MultiArc increases productivity but not complexity!

MultiArc – a new concept for arc welding

- Integrates more than one robot with one positioner using the new ABB controller IRC5.
- Developed in close co-operation with experienced customers in the automotive industry.
- Standard configurations for the majority of industrial arc welding applications.
- Superior accuracy, increased quality, faster cycle times, reduced need of floor space.
- Simple use, high up-time, versatility, flexibility

MultiArc is the perfect tool for arc welding.

For more information see www.abb.com/robotics

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Multiple robots, single solution

The Gordian knot of programming multiple robots

Jonas Anselmby

Robots have a well-established place in manufacturing. They are flexible, precise, cost-effective and will endlessly repeat complex task sequences with unwavering accuracy. But there are still many jobs that are too complex for a single robot. Just as an artisan may sometimes wish he had a third hand, so robot programmers desire extra robots for more flexible positioning or to work in tandem.

Putting additional robots into a cell does not solve all problems. If these are to move simultaneously, care must be taken to make sure movements are coordinated and paths do not collide. If one robot is difficult enough to program, then programming and coordinating several must be even more daunting. But not when using ABB's RobotStudio and the MultiMove PowerPac!

Within factory automation and especially arc welding, there is a clear trend towards systems with two or more robots connected to a single controller. This development is not primarily driven by robot product costs but by performance, quality and time-cycle issues.

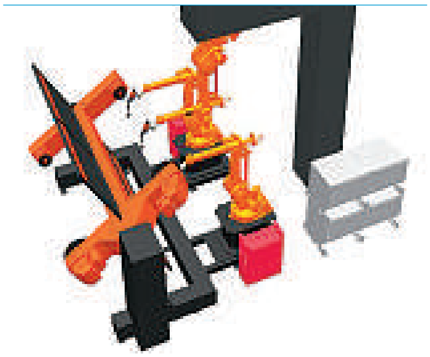
The market expects robot system manufacturers to offer multiple robot solutions. This is especially important in the automotive sub-supplier sector where such advantages can define the ability to remain competitive. The main application process is arc welding, especially in exhaust pipe, axle and seat production. Multi-robot systems offer advantages in terms of product quality, production rate and total system cost.

Why should multiple robot systems be especially suitable for arc welding? The following typical multi-robot welding applications require precise robot coordination:

- Two robots weld in coordination with respect to a moving workpiece positioner 1. This setup is called Twin Robots and is used where welding must be performed from both sides simultaneously to avoid material distortion.

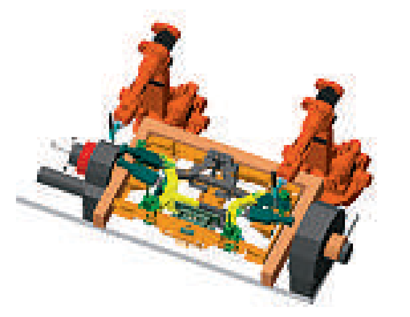
MultiRobot section

1 Robots welding in tandem in the Twin Robot configuration. Thermal effects may require both welds to be made simultaneously. Perfect synchronization is a must.



2 A smooth and perfect weld seam is obtained by the positioning and welding robot working hand in hand in the FlexPositioner setup.

3 When two robots can work on the same workpiece simultaneously, the need for an additional transport mechanism is saved.



- The workpiece is manipulated so that the welding bead is continuously oriented horizontally. One robot must position the work piece while a second robot handles the process equipment 2. This setup is called FlexPositioner.

Multi-robot systems enable better production rates and lower total system cost:

- Two or more robots can work with one workpiece simultaneously and so reduce the equipment necessary for transporting material between cells. This not only cuts cycle time, but also reduces the cost of the complete system 3.

IRC5

IRC5 is ABB's fifth generation robot controller. It is a product of ABB's trendsetting motion technology and uses an expandable modular concept. The IRC5 can synchronize up to four robots through the MultiMove™ function. It has a completely novel portable and ergonomic interface unit, the FlexPendant (see textbox).

MultiMove™

MultiMove, allows several robots to be coordinated with just one controller. These robots can operate independently or in coordination. This ability cuts cycle time and costs while improving quality and productivity. MultiMove's precise coordination makes manipulations possible that were previously considered impossible for robots.

RobotStudio™

ABB's simulation and offline programming software, RobotStudio, allows robot programs to be created in the office without production having to be shut down. Programs can be prepared in advance, increasing overall productivity.

2nd generation VirtualRobot™ technology

ABB's state-of-the-art VirtualRobot™ lets users run the actual controller code on their PC. This technology has driven competitors to follow ABB's lead.

The main paradigm of VirtualRobot technology is: If it works on the VirtualRobot on the PC, it will also work on the factory floor. The VirtualRobot can be used as a training, pre-sales and prototyping tool. It is ideal for concept studies, application development, test, and full simulations in RobotStudio. VirtualRobot is also a cornerstone in the strategy to provide customers with the highest value products for programming and integrating ABB robots.

The first VirtualRobot technology generation was implemented in products such as QuickTeach, ProgramMaker, and RobotStudio for S4. It was based on the fourth generation of ABB robot controllers, S4, S4C, S4C+.

Now, ten years later, ABB has released the second-generation VirtualRobot technology. This new generation is faster, handles multiple robots, and offers far more capabilities thanks to the strengths of the IRC5 controller. PowerPac

FlexPendant

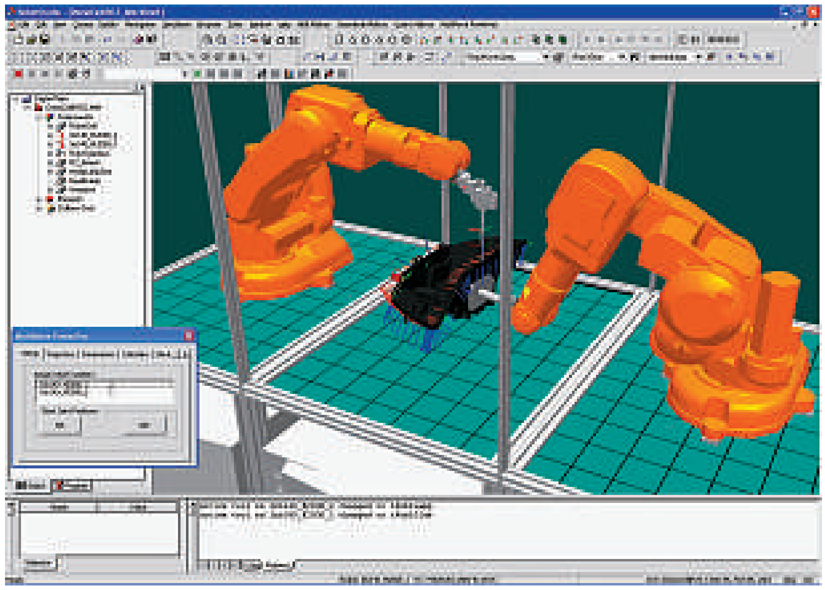
The FlexPendant is a hand-held robot-user interface for use with the IRC5 controller. It is used for manually controlling or programming a robot, or for making modifications or changing settings during operation. The FlexPendant can jog a robot through its program, or jog any of its axes to drive the robot to a desired position, and save and recall learnt positions and actions.

The ergonomically designed unit weighs less than 1.3 kg. It has a large color touch-screen, eight keys, a joystick and an emergency stop button.

The user-friendly interface is based on Microsoft's CE.NET system. It can display information in 12 languages of which three can be made active simultaneously, meaning languages can be changed during operation which is useful when staff from different countries work in the same factory. The display can be flipped by 180 degrees to make the FlexPendant suitable for left or right-handed operators. The options can be customized to suit the robot application.

PowerPacs are plug-ins for RobotStudio supporting specific applications such as welding, painting and cutting. These modules dramatically reduce preparation and setup time because this can be performed offline without disturbing production.

5 The MultiMove PowerPac of RobotStudio simplifies programming, testing and visualization of multiple robot situations.



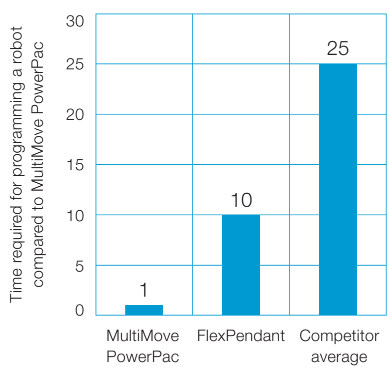
MultiMove PowerPac

MultiMove PowerPac is the new RobotStudio plug-in that cuts the Gordian knot of programming multiple robots. ABB is the first and only supplier to offer an offline planning, programming and simulation tool for a MultiMove system.

RobotStudio and the MultiMove PowerPac make multi-robot systems easy to plan, easy to program and easy to use 4. One of the principle benefits is simplified programming by focussing on technical production constraints only.

A common application of RobotStudio with MultiMove PowerPac is in defining a virtual robot cell 5. A path is created along the geometry of a part. This path can, for example, be associated with the geometry of the workpiece to be arc welded. The process parameters can then be defined as constraints to be considered in the control of the robots in the cell. Predetermined constraints can include, among others, tool orientation, cycle time and robot orientation. Optimization can be based on quality criteria such as: use of maximum speed through reducing the load on the limiting axis, minimizing cycle times, reducing mechanical stress on the complete system or individual axes.

4 Programming with MultiMove offers great time savings.



After constraints have been defined, MultiMove PowerPac automatically generates the robot paths.

ABB is the first and only supplier to offer an offline planning, programming and simulation tool for a MultiMove system.

In the following, the example of a two-robot arc-welding cell is considered. The process of automatically generating robot paths defines which tasks each of the two robots should execute, and defines the relationship between the two independently controllable robots. One of the robots can hold an object in a desired orientation while the second robot performs the arc weld along the specified path.

When paths have been decided, the robots' motion is automatically generated. Their interaction can then be verified in a simulation and subsequently downloaded to the controller of the real robots.

Thanks to MultiMove PowerPac, users can evaluate different cell layouts and production concepts in a very short time. MultiMove PowerPac makes a MultiMove system as easy to program and as flexible to modify as a single robot system.

With MultiMove PowerPac, ABB offers the best MultiMove offline-programming tool in the industry. There is, at present, no other working solution on the market.

RobotStudio™, VirtualRobot™, MultiMove™, PowerPac™, IRC5™, FlexPositioner™ are trademarks of ABB.

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Virtual and real

RobotStudio puts you in control of your robots – now both offline and online

Bertil Thorvaldsson

How do you teach a robot? Until recently, programmers had a robot at their disposal and took it through the cycle of instruction, test and correction until everything worked as desired. Under today's drive for higher productivity and competitiveness however, this method has one great drawback: The costly robot and all associated equipment have to be removed from the production process during programming.

ABB's RobotStudio offers an alternative. Instead of using a real robot, the programmer uses a virtual one. The robot is replaced by a desktop PC running the RobotStudio software. The software models the robot and all associated tooling and workpieces – the programmer can set up and test programs from the comfort of his office. But this is more than a mere simulation tool. The program that runs on the virtual robot can be downloaded to the real robot and this will behave exactly as its virtual counterpart.

At last programmers can test variants and perfection their programs without having to worry about the line manager getting on their heels because of the downtime they are causing. They can be confident that the robot is doing exactly what they think it is doing. Production planners don't have to spend sleepless nights over the productivity lost while programmers take possession of their robots.

Teach-pendant

Industrial robots have been around since the early 1970s. ABB delivered its first robot to a customer in 1974. This robot had to be programmed using a hand-held device called a teach-pendant. The robot was driven through the desired motion sequence using this pendant, and the robot-controller stored the sequence as a program that could be executed as often as required.

In the 1970s, when the use of a robot in itself created a competitive advantage, programming inefficiency could be tolerated. Today however, with everybody using robots in production, it is the companies that use them most efficiently that will prevail in the highly competitive market.

Technology may have made great advances in the 30 years that have since passed, and new and more efficient methods have been created for accomplishing many tasks, but surprisingly the 1970s procedure for programming robots is still widespread. Teach-pendants have, of course, evolved. Whereas the first unit was made of cast iron, had a very small alphanumeric display, and a large number of buttons, the new hand-held operator unit for the IRC5 is an ergonomic lightweight plastic unit with a large color touch-screen, a joystick, and very few buttons. But the basic principle of shop-floor programming remains unchanged and still has the same disadvantage; programming takes place at the expense of production.

Programming versus production

By using the robot, and worse still, all associated manufacturing equipment as a programming environment; the cost of programming includes the cost of the productivity that could have been derived had the equipment been producing. In the 1970s, when the use of a robot in itself created a competitive advantage, this inefficiency could often be tolerated. Today however, with everybody using robots in production, it is the companies that use them most efficiently that will prevail in the highly competitive market. This is driving a paradigm shift in the industry that, over a period of time, will revolutionize the way robots are programmed. This development is comparable to CAD software making drafting-board based mechanical design obsolete. The spread of offline programming tools for robots will consign "teach-pendant" programming 1 to the history books. ABB is leading this development with a software product called RobotStudio.

RobotStudio is based on the innovative concept, VirtualRobot™ technology. This was pioneered by ABB some ten years ago and has now been perfected into a second generation in conjunction with the development of the IRC5 robot controller. Using VirtualRobot technology means that the entire software that runs on the robot controller and on the operator unit has been converted to run on a regular Windows PC 2. Thus, unlike software products for robot simulation that have been around for a long time without making much impact on modernizing robot programming, RobotStudio is true virtual reality. In RobotStudio real robot programs run on real robot controllers. The only part that is

1 Online programming is becoming cost-prohibitive as competition intensifies. This picture shows the programming of the first ABB robot.

Product and tools

3 RobotStudio puts high productivity at the fingertips of all users of ABB robots.

4 With RobotStudio, editing of configuration parameters is swift and simple.

simulated is the mechanical unit where the steel has been replaced with a 3D model of it. Thus, what you see in RobotStudio is what you will see on the shop floor.

RobotStudio – lower costs and higher quality

RobotStudio can be used to reduce cost and increase productivity in every step of the life cycle of a robot system 3. In concept studies, it can improve the quality of the system: Proposed solutions are visualized to ensure that all people involved are talking about the same thing. When designing tooling and fixtures, RobotStudio can reduce the risk of unexpected costs and delays by verifying designs before they are manufactured. And, above all, by programming the system while the real robots are still hard at work on the previous job, production can start earlier and time-to-market is reduced. Product quality will also increase as robot positions are taken directly from the CAD-model of the part, without influence of the online programmers varying skill with the joystick. Once the system is producing, it is possible to fine-tune it without sacrificing production time. Finally, as new variants of the part are introduced, reprogramming is possible while the system continues to produce.

With the second generation of VirtualRobot technology, differences between real and virtual robots have been eliminated to the extent that RobotStudio can run with real robots. RobotStudio can connect to real robots on the shop floor using a network connection and can modify programs and parameters in these robots. This is particularly useful when setting up new robot systems. Previously, technicians on the shop floor had to make do with hand-held operator units to define or modify parameters in robot controllers. The lack of a keyboard and a high-resolution display made this tedious and time-consuming. Now, they can simply connect a portable PC to the robot and use RobotStudio to make adjustments quickly and easily 4. The leap in efficiency is so great that ABB includes a small subset of RobotStudio with every robot shipped so that no customer has to settle for the configuration methods of the past.

2 With VirtualRobot technology, a robot can be put onto every robot user's desktop.

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Traced to the source

WebWare takes the headache out of catching errors in discrete manufacturing

Anders Ekblad

Many production lines will sporadically churn out suboptimal parts. Some such defective parts are detected before they leave the factory. Others are returned by the customer, or worse still, fail in use causing considerable costs and damage. Reducing the count of such bad parts represents a considerable potential for improving quality and cutting costs in practically any branch of manufacturing.

If only the manufacturer could reconstruct exactly what it was that went wrong when the faulty part was made. Was there an incorrect welding setting? Did somebody make the wrong adjustment to the robot?

Unfortunately, such details are often recorded only in the heads of production personnel and forgotten before they can be analyzed.

WebWare from ABB changes all of this. Even the most minute of changes is recorded. The exact conditions under which every individual part was manufactured can be reconstructed long after that part left the factory. If a problem occurs, all parts that may have the same problem can quickly be tracked and the parts recalled. This cuts down on uncertainty and on the costs and disturbance of unnecessarily recalling good parts. Imagine the disruption, for example, if a drinks company must recall all bottles filled during a certain period because it cannot trace the problem more precisely, or of a pharmaceutical company recalling all its pills because it doesn't know which ones are dangerous. Waste is no longer a question of bad luck but can be managed. That's one headache less for production personnel and one bonus for quality!

The need for control of discrete manufacturing processes

To reach best in class in discrete manufacturing is half the battle, remaining at the top is the other half. The challenges of shortening product life-cycles and constant price pressure are some of the threats that must be faced; only companies that manufacture world-class products with world-class efficiency will win.

World-class manufacturing requires world-class control of the production assets. ABB's WebWare product gives customers that control. Being in control allows customers to make quicker and better business, technology and operating decisions.

WebWare gives customers the opportunity to look deep into their robotics process and develop solutions to questions such as:

- How can I shorten cycle time by 25%?
- How can I increase quality and reduce the potential for costly product recalls?

Product and tools

- How can I increase overall equipment effectiveness by 10%?
- How can I reduce downtime due to unplanned service needs by 30%?
- How can I eliminate downtimes caused by loss of data on the factory floor?

Actionable Information Creates Control
In today's information society, it is easy to gain access to enormous quantities of data. But data alone puts nobody in control. The key to succeeding in today's business environment is "actionable information": the right information at the right time for the right people. This is the vision behind WebWare.

In a nutshell, WebWare transforms factory floor data into actionable information and enables business excellence.

Being in control means knowing the status of production assets at any time and foreseeing where problems may arise.

WebWare – A flexible solution
WebWare is an IT based system that collects and records all necessary data and makes it available in an actionable form.

WebWare has been carefully designed using industry standard tools to offer both a standard 'out of the box' solution, as well as the ability to customize packages to meet individual requirements and work with legacy systems. In this way, ABB protects the investments of its customers.

WebWare is built with a modular framework based on proven technologies and ABB's knowledge of process and robot technology. WebWare technology is scalable, and can serve from large companies with more than 1000 robots down to small operations with less than ten robots.

To achieve this scalability, WebWare uses the concept of data collectors. Data collectors manage the communication to and from a group of robot controllers (typically around 30). Each data collector feeds this information to the WebWare Server where the information is stored. An unlimited number of data collectors can be connected to the WebWare Server, enabling it to communicate with a very large number of robot controllers.

The information stored in the WebWare Server is accessible from any client with Internet Explorer through ASP .NET pages. Hence, the information is available anywhere and anytime, putting customers in control.

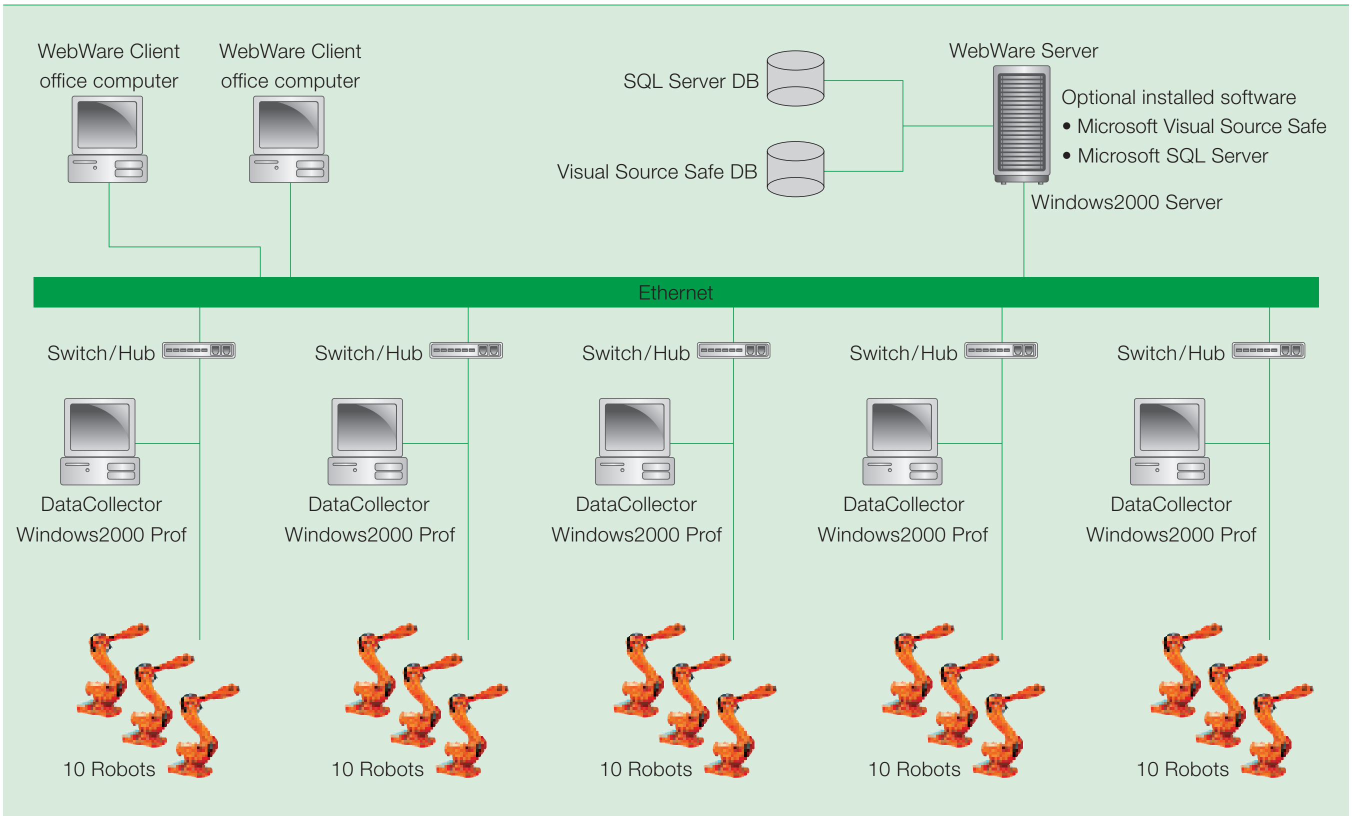
Add-in modules give customers the needed functionality. When change is needed, it's simply a question of adding a module.

The following modules are currently available for WebWare: BACKUP and REPORT.

BACKUP
This module safeguards robot data by scheduling automatic backup and permanent archiving of robot programs, configuration files, and other production files from the robot or any other automation device with an FTP interface.

BACKUP also includes a connection to Microsoft Visual Source Safe, allowing users to review program changes

1 Typical WebWare setup permitting traceability.



when investigating unintended variations in production quality or performance. Up-to-date file archives are key to rapid recovery in the event of equipment substitution, failure, or rebooting.

As a minimum, every customer needs this inexpensive "insurance" against unforeseen data loss on the factory floor.

REPORT

The REPORT module offers extensive visual and personalized information that is actionable and "appropriate" to the user. The concept of "appropriateness" is a key factor in making information actionable. REPORT makes it easy for everyone, from shop floor workers to business managers, to monitor the metrics that matter most for their particular needs and responsibilities.

REPORT puts key performance indicators at the user's fingertips, making proactive and predictive business management a reality. This allows personnel at all levels to keep track of the relevant metrics in real time. Everybody can now manage expectations, monitor trends, and make intelligent decisions based on actionable information.

Several other add-in modules are currently under development and will be announced during 2005 and onwards.

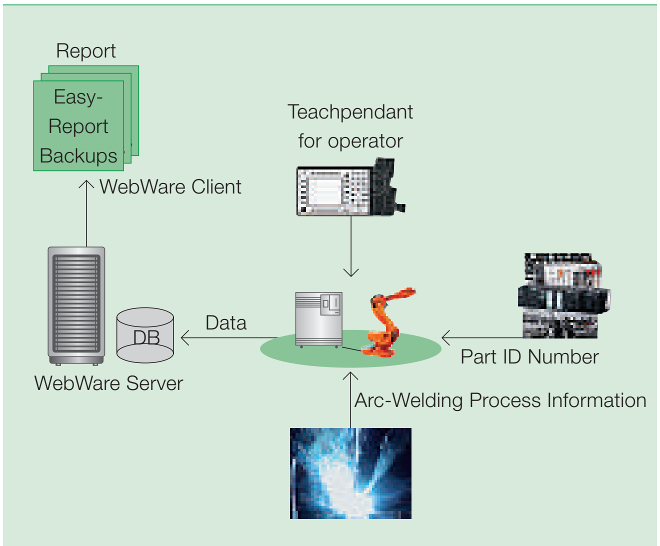
Traceability

Being in control is not only about control of production equipment, but also having control over the quality of parts produced. Many customers ask themselves:

- How can production quality be optimized?
- How can zero-error-delivery be achieved?
- How can errors be prevented?

Since the ABB robot is involved in many of the processes, such as arc welding, the robot controller is important in obtaining quality data from the welding process. This opens the possibility of monitoring and tracing the result as parts are refined. A typical traceability solution includes the components shown in 1.

2 Reporting structure.



The robot controller is pivotal. It gathers information from the arc-welding process, collects the ID of the part produced and actions taken by the operator. For each robot controller, all this information is constantly fed to the WebWare server database 2. Once in the WebWare database, quality information for every part produced is made available either as reports in the WebWare client, or alternatively forwarded to business systems such as SAP.

As a result, the company gets a "birth certificate" for each part. This certificate can be tailored to include relevant and appropriate information such as:

- Serial number of the part.
- Which operator was responsible and whether any changes were made to program or process parameters.
- Result from every welding operation performed on the part and any process errors that occurred. If appropriate these include deviations from nominal voltage, current and stick-out, and the exact position on the seam where these occurred. Such data is valuable for debugging.

Being able to track the exact conditions under which every individual part was manufactured simplifies the recalling of faulty parts. If a problematic production setting is discovered, a quick search on the database will pinpoint all parts afflicted by this problem. These are then recalled. A blanket recall of all parts and the associated costs and disruptions are avoided.

What Can WebWare do for the customer today?

WebWare is easy to install and operate. A typical installation takes less than a week. Once installed, WebWare helps customers gain control of their production and provides them with actionable information. This information helps them answer important questions such as:

- How can the production line be continuously optimized against downtime and/or bottlenecks?
- How can data in robots best be safeguarded and how fast can one robot or the whole line be restored? This option is especially significant in view of the real costs of downtime.
- Production data is often captured and stored in a database. Can it be quickly accessed for critical decisions, or is the data trapped in information islands where the format is hard to read or even inaccessible?
- How can the quality of parts produced be traced and proven to customers?

For anybody involved in discrete manufacturing, having the answers to any of these questions will surely take the headache out of operations.

WebWare is part of the overall Industrial IT strategy from ABB. Today more than 1000 companies benefit from the strengths of their Industrial IT solutions. WebWare has been carefully designed to meet the needs of robotized discrete manufacturing solutions.

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Painting the future of robotics

Future technologies for interactive robot programming

John Pretlove, Charlotte Skourup, Thomas Pettersen

Robot programming has made huge strides during the last 30 years. The concept of a robot programmer hacking cryptic commands into a dumb terminal has long ago given way to ergonomic tools such as the Flexpendant and RobotStudio. Now, another leap is coming. Programmers will move away from their computer screens and enter a virtual world with which they will interact in three dimensions.

When teaching a robot to paint, they will use a virtual paint gun to specify the robot path together with process related information while getting direct real-time visual feedback of the simulated process through a head-worn display.

This new approach creates a tool for making robot programs in a fast and intuitive way, enabling a craftsman on the shop floor to program an advanced and complex robot system without having to be a computer expert. This has the advantages of being easy to use and cheap, but most of all can capitalise on the process expert's knowledge.

Traditionally there are two methods for programming robots: Manual robot programming systems using the actual robot and CAD-based systems for programming away from the robot.

Manual robot programming systems guide the robot through a series of waypoints by hand or through interaction with a teach pendant wired to the robot. A teach pendant typically consists of a display, a keyboard and often a joystick. In order to specify a robot program, the operator works directly with the robot using the teach pendant to move the end-effector around the object to record position, orientation and process-specific information.

Teach pendant solutions are cumbersome and time-consuming. Additionally, the programmer has no direct visual feedback of the result; he sees the manipulator and how it moves in relation to the object, but has to remember and mentally visualize where he has recorded previous robot waypoints. Secondly, using a joystick with three degrees-of-freedom to steer a manipulator with at least six is inconvenient and not exactly intuitive. Thirdly, the task of specifying path and process related information often takes at least two separate iterations, making it difficult for the process expert to utilize his knowledge in an effective manner.

CAD-based programming, on the other hand, is traditionally performed on a computer workstation where 3D CAD models replace the real robot and the object. The robot program can be simulated and edited before being downloaded to the robot.

These systems tend to be expensive and are often complex with a large number of functions that require a long training period before they can be used efficiently and effectively. Neither is it trivial for the operator to interact with a complete virtual 3D environment using standard workstation I/O devices. In addition, a full 3D model of the object, the work cell and the robot is required. Perhaps the biggest drawback, however, is that programming is moved away from the hands of the craftsman on the shop floor.

Both of these traditional methods have advantages and disadvantages, but both are, in general, time-consuming, error prone and often require several iterations before the program is acceptable. Generating a new robot program is an extremely complex and demanding process, often requiring the participation of more than one person. Depending on the quality requirements, complexity of the object, complexity of the process, cycle time, skill level and experience of the robot programmer, it may take from under an hour to several weeks to make a robot program.

By utilizing this wearable programming system the operator can freely move around the object and visualize the simulated result of the paint process before the actual painting is performed by the robot.

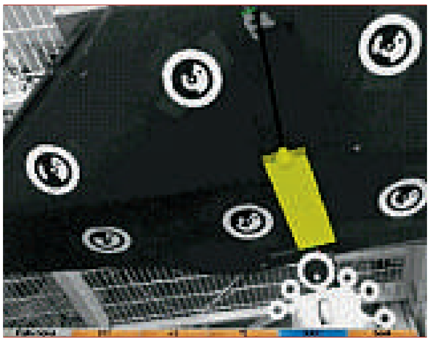
This article presents a new approach that delivers an easy to use AR (augmented reality) -based robot programming tool taking advantage of the operator's implicit process & domain knowledge and generating high quality programs in one single iteration. It combines the advantages of both CAD-based programming (simulation and visualization of the final result) and manual robot programming (direct specification of the process on the real object).

artVIS – augmented reality for task visualisation

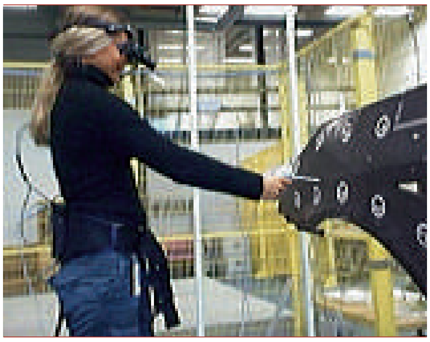
This new robot programming system provides real-time visual feedback for the robot programmer. The system utilises augmented reality, a technique that overlays computer-generated (virtual) information with the real world scene, presenting this to the programmer on a head-worn display [1]. The programmer looks at the real object and sees dynamically updated graphics as if they were physically attached to the object. For example in paint applications, the virtual information represents the path of the tool in relation to the object during execution. In addition the width and colour of the paint-strokes, the orientation of the paint-gun along the path and other process properties are presented 1. The system allows for real-time simulation of the tool along the programmed path by "playing" the actions of the tool along the robot path. By utilizing this wearable programming system the operator can freely move around the object and visualize the simulated result of the paint process before the actual painting is performed by the robot. This advanced visualization enables the operator to focus on the process rather than having to generate his own mental model of the program.

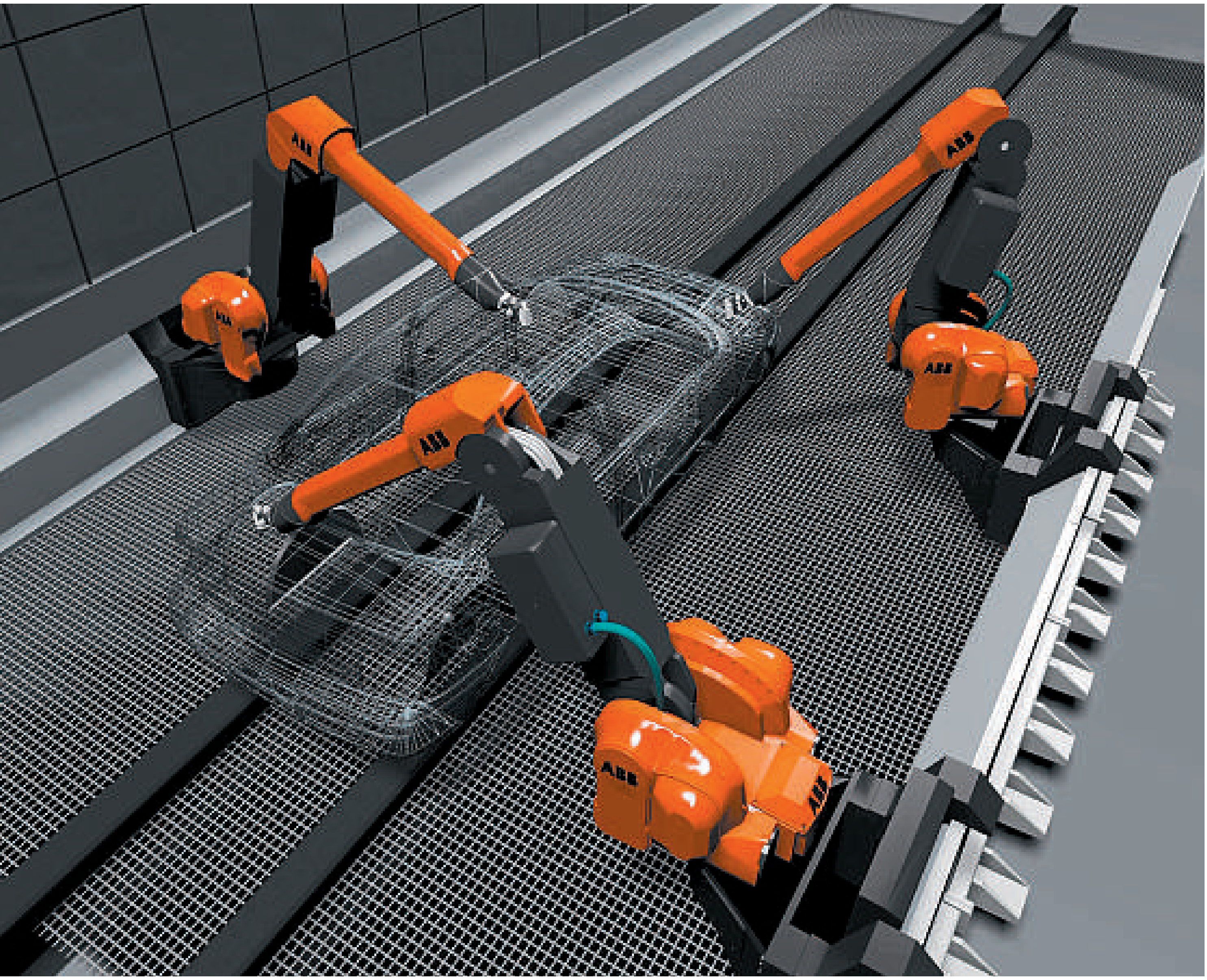
The composite augmented reality view is most conveniently displayed

1 The composite Augmented Reality view as seen by the operator. This figure shows a car wing with six unique markers attached to it for location purposes. The yellow strip is virtual paint that has been applied by the operator and is overlaid in the operators view.



2 The operator specifies target points using a hand-held device directly in relation to the object to be painted. The simulated result is displayed as a composite image on headworn displays 1.





on a head-worn display with an integrated camera 2.

In addition to capturing the real world scene, the camera system also comprises a vision-based tracking system that enables correct registration of the simulated process result. The tracking is made possible by attaching automatically configurable visual markers to the object.

Programming and editing is done through a wireless pointing device mimicking the real process paint gun. The device is tracked with six degrees of freedom enabling the specifications of path waypoints and process related information directly in relation to the object. The pointing device has a number of interaction buttons through which the operator can easily specify or change program properties; the operator simply pushes a button to specify or delete a waypoint.

> Programming and editing is done through a wireless pointing device mimicking the real process paint gun.

Editing of the manipulator path is simply done by dragging a waypoint to a new position. The virtual graphics are continuously updated in such a way that the changes made to the program are visualized instantly. For example by changing the width of a paint-stroke, the process quality related to paint coverage can be inspected.

After the robot program has been specified, robot instructions are generated automatically and downloaded to the robot controller for execution.

Prototype testing
Initial benchmarking tests showed that robot programming using this novel robot programming prototype system achieved the goal of being at least

twice as fast as conventional programming methods.

Today's prototype makes up a complete system with full functionality for generating a new robot program including set-up and configuration, creating the robot program, real-time reachability check, editing and generation of robot programming code. The prototype system fulfils all the requirements regarding set-up and configuration (less than 1 day) and training of (new) users in less than 3 days. The prototype system also fulfils the requirement of accuracy (x, y and z deviation below 5 mm).

The possibilities demonstrated here are only the beginning of the possibilities offered by AR. Besides simplifying robot programming, the technology will revolutionize other applications – not just within robot programming, but also for other applications such as service and maintenance

By utilizing the benefits from both CAD-based and manual robot programming methods, process experts are able to generate high quality robot programs in an efficient manner without extensive training. The new method is therefore attractive across the market segments but particularly for smaller sized process or production enterprises which have previously not seen industrial robots as cost-effective tools because of the difficulties of using and programming them.

Feedback from operators indicates that this combination of virtual paint applied to a real object is very effective and convincing- and the operator quickly forgets that the paint is only virtual.

An exciting future

The possibilities demonstrated here are only the beginning of the possibilities offered by AR. Besides simplifying robot programming, the technology will revolutionize other applications - not just within robot programming, but also for other applications such as service and maintenance. AR represents a paradigm shift for 'Ease-of-use' of technical systems. Corporate Research Center, Norway, has introduced a totally new but very powerful technology.

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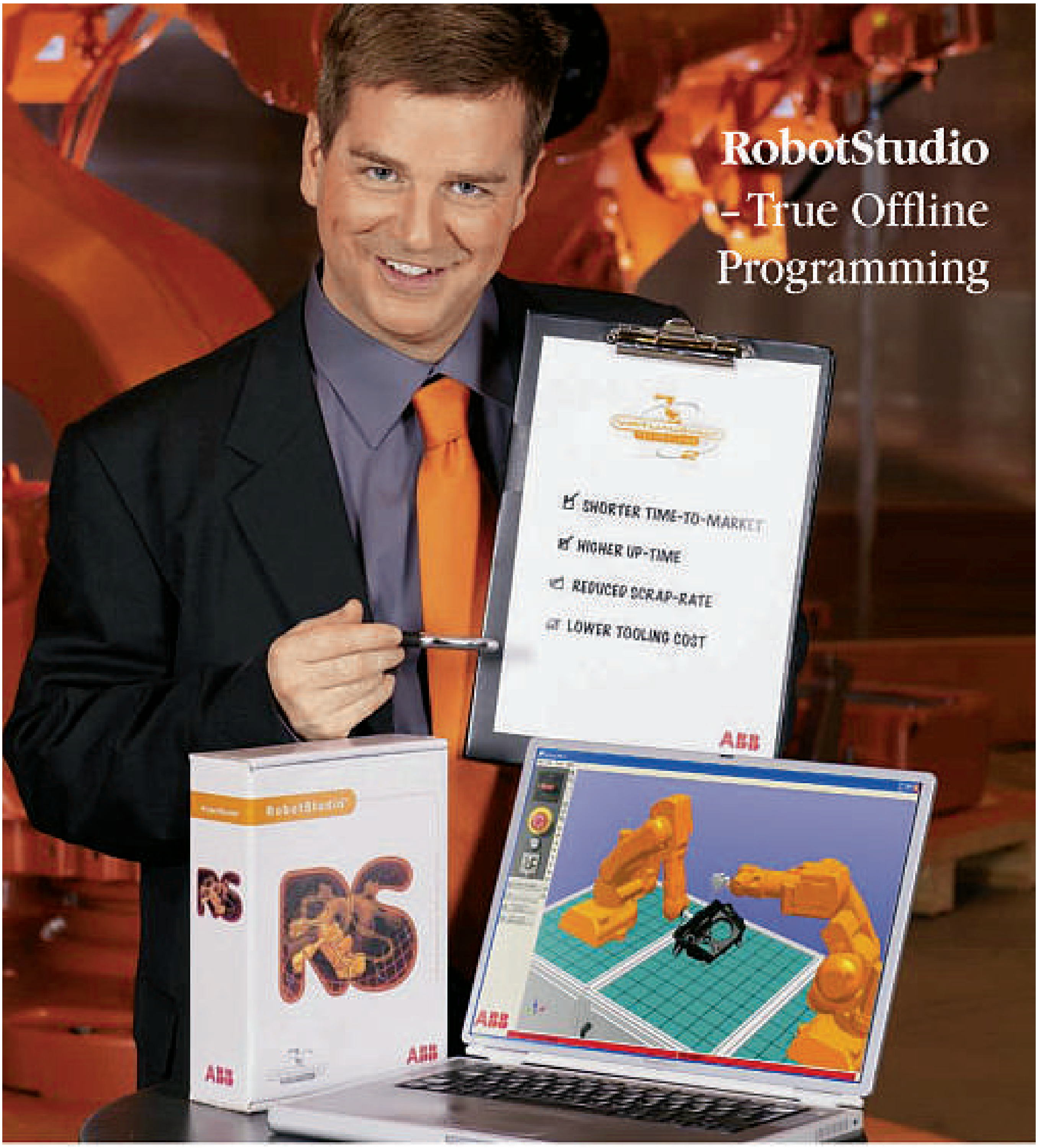
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