New robot improves cost-efficiency of spot welding

A newly developed compact robot system dubbed IRB 6400C is helping to increase the productivity of spot welding and assembly lines in the automotive industry and at the same time reduce their first-time and operating costs. Due to the system's compactness and three different work envelopes, more robots can be operated in a welding station than in the past. Leaner, more efficient production is possible as a result.

Working together with ABB Flexible Automation and carmakers, ABB Robotics Products has developed a new robot system, designated IRB 6400C, for spot welding and assembly lines in the automotive industry 1. Also new is the S4 SpotWare robot controller, which offers special functions for improving the overall efficiency of the welding stations [1].

As a result of a new space-saving concept featuring three different work envelopes, more robots can be installed in a welding station than in the past. Fewer welding stations are therefore required for the same number of robots, allowing shorter welding and assembly lines.

The benefits of the new robot system can be summarized as follows:

- Lower first-time and operating costs for spot-weld lines, due to fewer welding stations and less ancillary equipment. Shorter, simpler transport systems are required; less floor space is needed. Project engineering work is reduced, also maintenance and service costs and the power and compressed-air requirements.
- Production cycles are shorter; fewer semi-finished car bodies are on the line at any one time. Production is not interrupted every time a 'gun' (electrode holder) has to be repaired or serviced. Spot weld numbers can be changed as required, while the assembly line can be easily extended by adding further compact robots.
- Large work envelopes, high load-handling capability and high reliability.
- Shortened product lead times for spot welding and assembly lines.
- Safer maintenance of welding and assembly lines. The new robot's 'bend-back' and 'turn-back' (180°) capability allows maintenance of the guns outside of the danger zone.
- Field-proven technology; the robot system belongs to the well-proven IRB 6400 robot family. More than 7000 IRB 6000/6400 systems for spot-welding car bodies have been installed worldwide to date.
- The robots are compact and of rugged design. Mechanical parts are made of nodular cast iron and designed as modules.

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Lower first-time and production costs

The IRB 6400C robot system was developed to meet the automotive industry's urgent need for reduced first-time and production costs for assembly lines and welding stations. It is designed primarily for spot welding, either in stand-alone applications or in combination with the assembly of engine compartment parts, underbodies and side members, as well as for the final assembly of the main bodies. However, its versatility, space-saving design and adaptable working envelope also makes the robot well-suited for other applications. The space-saving design, in particular, allows up to eight compact IRB 6400C robots to be installed on the floor space taken up by a single spot-welding station, for example for assembling underbodies or main bodies 2.

The current trend for assembly lines (eg, for the main bodies) is towards greater versatility. More emphasis is also being placed on wider uses for robots rather than on simply automating the spot-welding process.

New tool-handling systems with flexible fixtures, transport systems with rotating magazines, and more compact spot-welding robots, not only allow different models of the same car family but also totally different car bodies to be assembled on the same production line 3.

Leading carmakers are already investing in IRB 6400C robot systems for their assembly lines. The saving in total in-

The new compact IRB 6400C robot being put through its paces during a demonstration for sales personnel 1

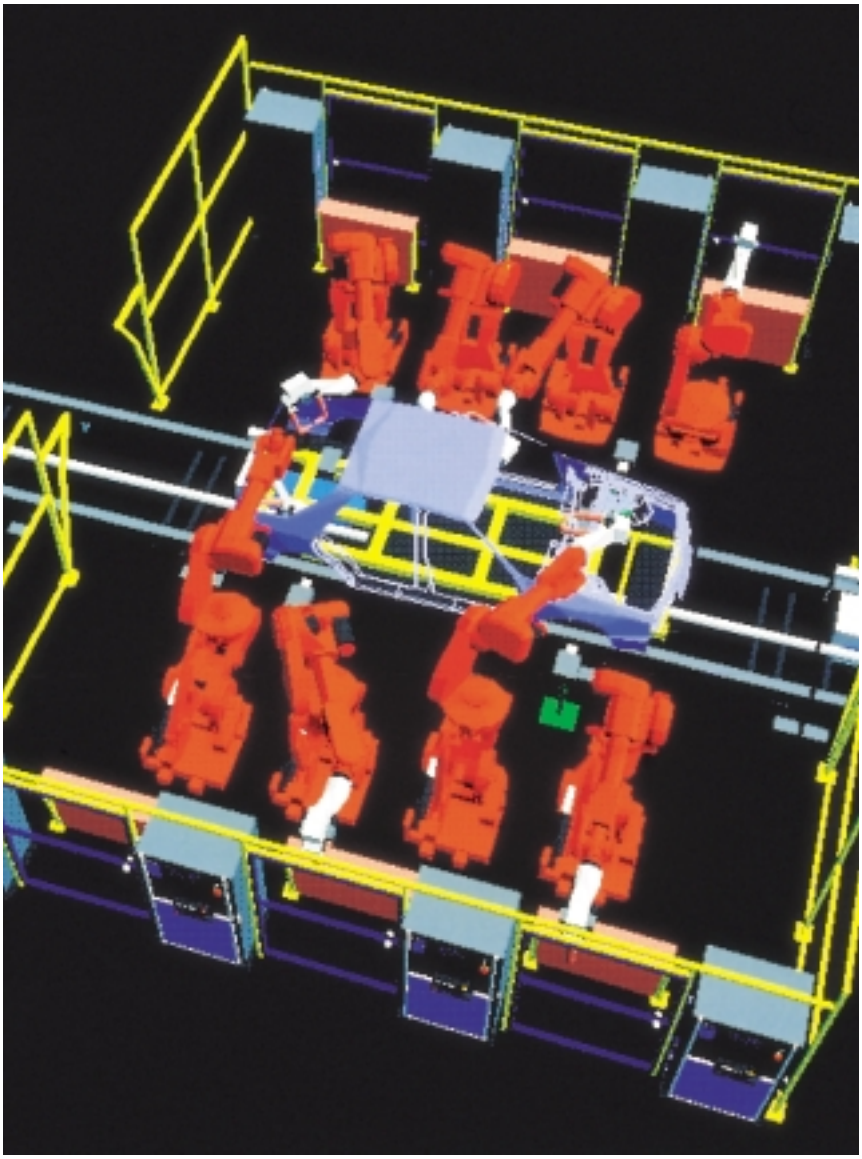
vestment costs is estimated at almost 20 percent compared with installations that work with conventional spot-welding robots.

Six versions of the robot are available

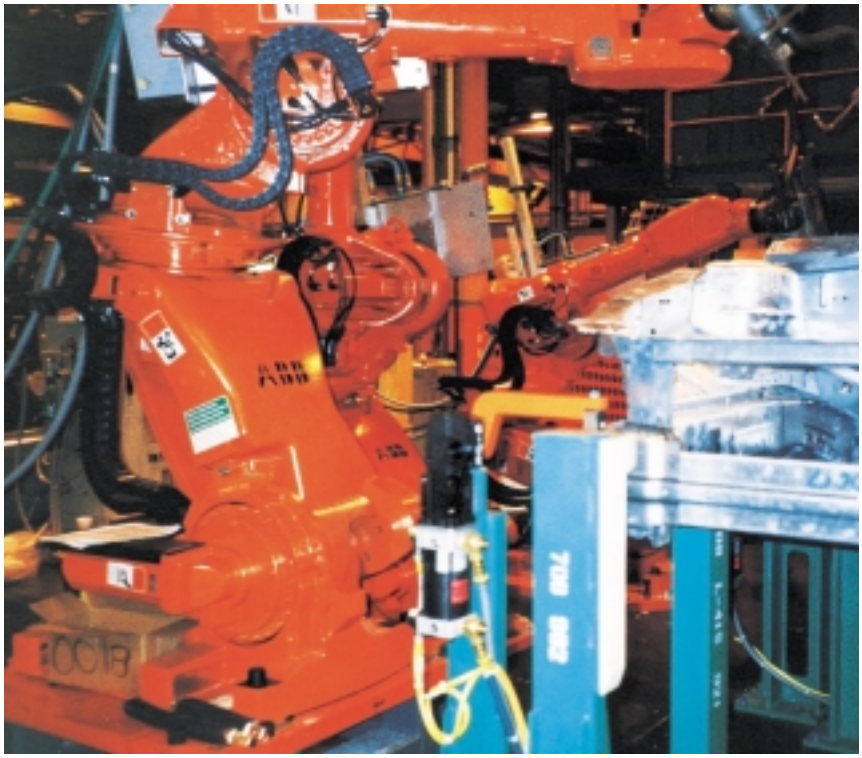
The IRB 6400C robot family is available in six different versions. Three different work envelopes are possible and the handling capacity of the robots varies in the range of 120 to 150 kg. Due to the modular design, the construction of the different robot versions differ only slightly from one another. Only the software, the cabling and the drives for the axes 4, 5 and 6 are different in each case.

Like its predecessors with a traditional articulated arm, the new IRB 6400C robot has six axes (degrees of freedom), although axes 1 and 2 are transposed 4. Axis 1 on the earlier robots now corresponds to the bend-back motion, and axis 2 to the turn-back (or swing) motion, making the robot more compact. Up to eight robots can now be installed around each car body, thus meeting the automotive industry's requirements.

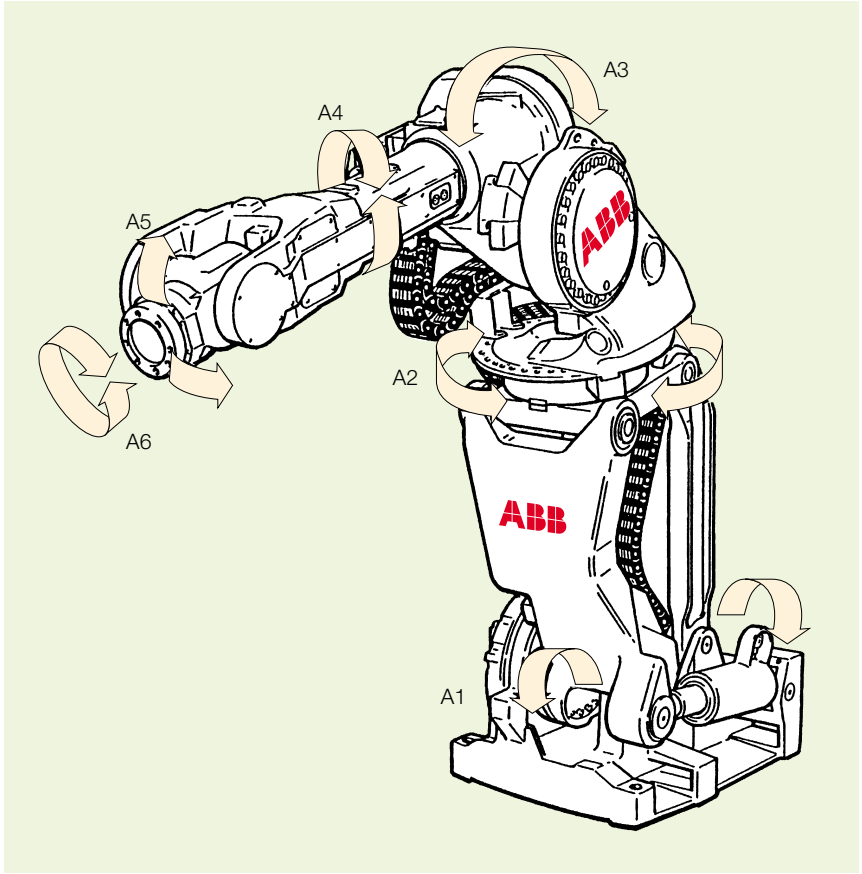
Due to the agility provided by axis 1, the front work envelope of the new robot is at least as large as that of the IRB 6400 robots. The IRB 6400C's relatively small external dimensions nevertheless place it firmly among the smaller robot types. In two of the six available versions, the robot arm can also be bent back-



Eight floor-mounted compact IRB 6400C robots (four on each side of the cell) can easily perform all the spot welding operations on a car body. 2



IRB 6400C robot welding a car underbody 3



wards through 180° (axis 3). Wrist axes 4, 5 and 6 are similar to those of the IRB 6400 robot.

A technical feature of axis 1 is that the strut at the back of the robot does not run parallel to the lower arm. The development of the new robot system therefore involved more research and software calculations than in the case of robots with a traditional articulated arm.

The work envelope, width and height of the IRB 6400C make it one of the best compact robots available on the market today.

A powerful drive package

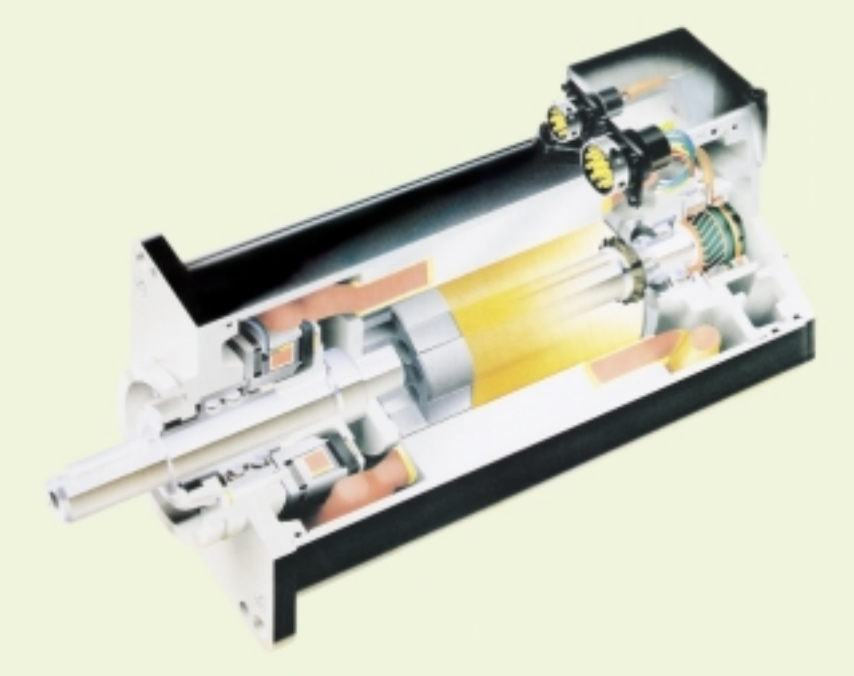
The drive package for axes 1, 2 and 3 consists of electric motors and gear units, and has been integrated in the IRB 6400C robot in a way that contributes to its compactness. The cables, unlike those of other ABB robots, lie outside of the mechanical structure. This makes design changes easier.

Each of the parts performs multiple functions, thereby reducing the number of modules by about 20 percent compared with the IRB 6400.

The drives, which are permanent-field synchronous machines 5, are basically of the same design as the drives used in the IRB 2000 robots. These were developed in the mid-1980s and have been continually improved over the years. The ongoing development has resulted in

Axes (A) of a compact IRB 6400C robot 4

Axis 1	*Backwards/forwards bending of robot body*
Axis 2	*Turn-back of upper part, to right or left*
Axis 3	*Tilting of robot arm, upwards or downwards*
Axis 4	*Twisting of robot arm about longitudinal axis*
Axis 5	*Movement of wrist about horizontal axis*
Axis 6	*Twisting of wrist or tool flange about longitudinal axis of robot arm*



Section through the compact gear unit for a robot with power transmission 6

Section through a permanent field synchronous motor. This kind of motor drives all six robot axes. 5

smaller, more powerful machines which can be custom-designed for specific tasks and are ideally suited for different families of robots. Power is supplied via a three-phase frequency converter. The motor-related functions are implemented in the robot computer software.

Compact gear units 6 transmit the power required by the axes 1, 2 and 3. Their basic design and the way they function are described briefly in the following:

Several two-stage planet pinions revolve around the circumference of two separate rings (the 'stator' and 'rotor'), being meshed with their inner toothed rims. The input shaft, located in the center of the gear unit, drives the first stage of the planet pinions. The second stage of each pinion drives the rotor ring, which acts as the output 'shaft' of the gearing.

The compactness of the gears for axes 1, 2 and 3 is also helped by the main bearing for each axis – a cross roller bearing – being integrated in the gear unit.

The drive package was optimized before the prototype was built by simulating the robot cycle times with the aid of special software. The moment of force could be largely compensated for by means of a nitrogen gas spring. This feature has made the drive package for axis 1 more compact as well as less expensive to build.

Three different work envelopes are available

Customers can choose between three work envelopes. Each envelope has a separate designation (an extra letter attached to the robot family type) and is designed to be used for certain operations and in certain locations in the welding station. The main working area for type IRB 6400C/B, for example, is in front of the robot 7. The robot's arm bends back through 180° for easier maintenance of the welding gun. For a combination of spot welding and handling operations (including maintenance of the gun), a robot can be selected with the same large work envelope at the front as the 'B' type, but which can also be swung back 200° to the right (IRB 6400C/R) or to the left (IRB 6400C/L).

Special functions for spot welding

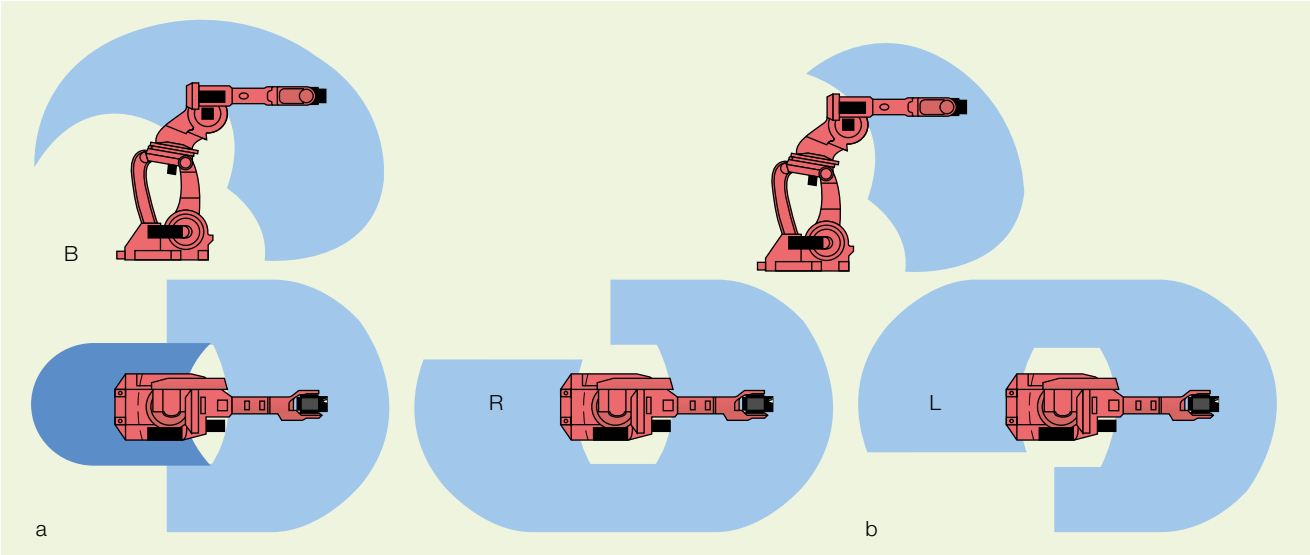
The IRB 6400C robot is equipped with the S4 SpotWare controller, which has special functions for improving the overall efficiency of the spot welding station. Three of the available functions are given below:

Gun closing

Closing of the welding gun can be started even before the programmed weld position has been reached 8. To close the gun according to plan (ie, independently of the speed at which the arm is moving) all the operator has to do is define the exact closing time. Cycle times are optimized by the gun closing completely just as it reaches the weld position.

Fast travel to the next weld position

The robot is set in motion as soon as the start signal is given, the next movement being prepared before welding in the current position has been completed.



Work envelopes of the different versions of the IRB 6400C robot 7

a *IRB 6400C/B (bend-back)*

b *IRB 6400C/R (turn-back, right) and IRB 6400C/L (turn-back, left)*

Extended customer routines and parameters

The robot can operate with different welding intervals and types of gun. The signals for the chronological sequence given by the welding control program 9, the gun sequence and the robot movements, can be easily adapted to different conditions.

Movement of the gun to the next weld position can be started either through a start signal given by the operator or automatically, in which case starting is delayed for a defined time after the previous welding operation.

The program can be tested in stand-alone mode, ie, without the weld timer or the gun being connected. This makes testing considerably easier.

The control has been designed for double guns, small as well as large movements, and different electrode pressures. Several guns can be controlled with the same program.

User-specific routines are possible in

Process tuning is made easier by a special programming device, on which the spot welding parameters are set. 9

The welding gun starts to close before the robot reaches the weld position, thus minimizing the time between the spot welds. 8

With the help of simulation software, spot welding station configurations can be optimized before the equipment is installed. The spot welding program is generated in off-line mode. 10

Advanced production technology is used in the manufacture of the new compact robot. Here, an ABB painting robot applies the primer coat to an IRB 6400C. 11

the event of process disturbances. Such a routine could be, for example, a manual command telling the robot to move into the service position. After maintenance, welding continues at exactly that point at which it stopped.

Realistic robot simulation with CAR Tool

CAR Tool is a software package for computer graphics based planning, simulation and off-line programming of industrial robots that has gained growing acceptance in the automotive industry in recent years. To make it easier to gain access to the robot data contained in CAR Tool, simulation equipment vendors, the automotive industry and robot suppliers have joined together to develop the so-called Realistic Robot Simulation (RRS) interface 10.

ABB Robotics Products has developed a robot controller simulation (RCS) module for the IRB 6400C robot. In combination with CAR Tool's computer graphics support, this module allows a precise simulation of the robot motion pattern and of the operating times applying to a specific spot welding cell.

The RRS interface has made it significantly easier to combine different robot data and different types of graphics-supported tools, while the same interface is also a valuable tool for planning spot-welding lines. Spot-welding operations of different robots are easier to optimize when it is used.

A member of the 'New Product Line'

With its compact IRB 6400C, ABB has introduced a robot family that meets the automotive industry's demand for higher productivity and a constant high quality for its welding and assembly operations, plus easier robot implementation and an affordable price 11. The new compact robot family allows an increase in the productivity of car body welding and assembly lines compared with lines with conventional robots, as well as a reduction in both the first-time costs and floor space required.

References

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