First robotized assembly line for multivalve cylinder heads in Europe

From its earliest days the automotive industry has pioneered the automation of factory operations. This reputation is being added to by yet another new development in the assembly area. The trendsetter is ABB Flexible Automation GmbH, based in Butzbach, Germany, which has developed a future-oriented concept for vehicle engine assembly in which jointed-arm robots play a key role. The new concept has been adopted for Europe's first robotized assembly line for multivalve cylinder heads, installed by ABB for the German carmaker Audi in Györ, Hungary.

New market trends are forcing automobile manufacturers to introduce new car models at increasingly faster rates. To meet this requirement, production plant has to be more flexible and at the same time capable of being put into operation quicker than before. Moreover, capital investment and production costs have to be reduced and product quality and plant availability significantly improved. These trends are making enormous demands on the plant suppliers.

The challenge is being met by ABB Flexible Automation GmbH in the form of a future-oriented concept for the assembly of car engines, cylinder heads and axles. The main difference between this concept and assembly methods employed in the past is that the new method makes use of robots for the vast majority of the assembly work. Hitherto, robots were considered to be mostly unsuitable for such applications, and it was reckoned that no overwhelming cost advantages could be gained by using them in the production area. Assembly lines installed by ABB, however, show impressively that this is not the case. While the targeted results cannot be achieved with robots alone, by widening their use and integrating other automation features, such as programmable controllers, production control, modular transport systems and modern drive, measurement and test technologies, total systems can be created that offer completely new answers to the industry's problems. The robots' inherent advantages, for example improved performance and flexibility, plus lower costs – all benefits also offered by robots in stand-alone applications – add extra value to the new concept.

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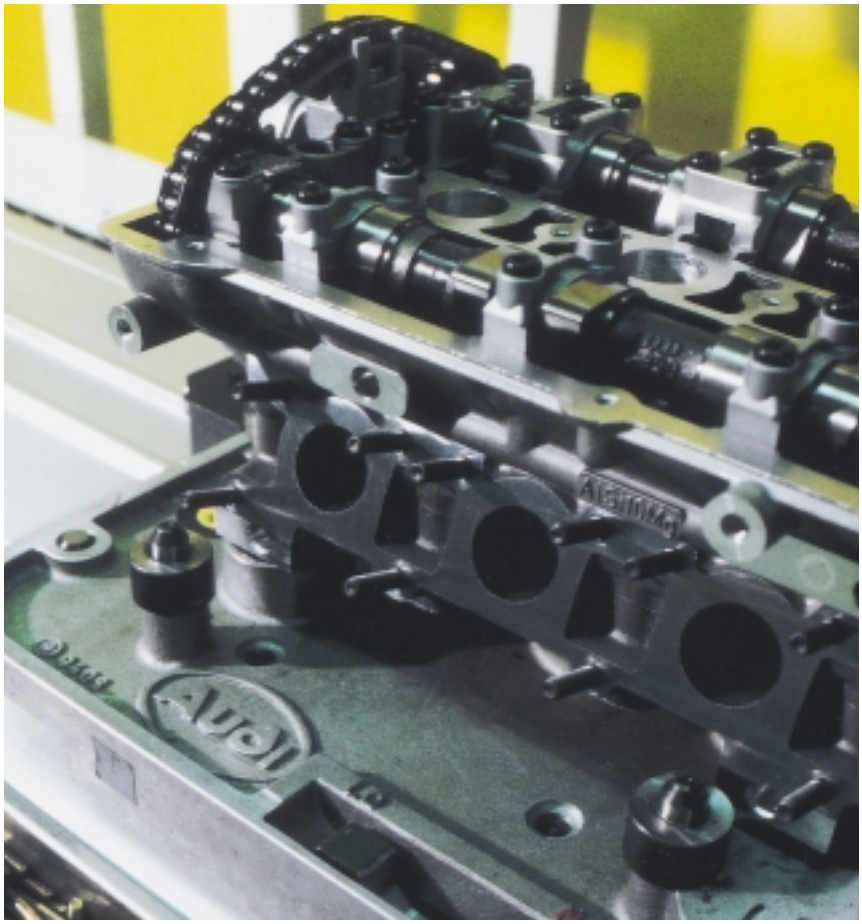
Development of robot technology

Robots have become the new option for assembly work as a result of the rapid advances in robot technology over the past decade. Modern robots are not only about 40 percent faster than their predecessors but also perform with a substantially better load-handling capability (+50 percent) and work envelope (+20 percent, *Table 1*). What is more, their accuracy has been improved to a level which is more than sufficient for assembly work. In other words, the use of robots can be justified today on the basis of the quality that can be achieved with them. Also improved is their availability, which now stands at almost 100 percent. This secures a very high overall plant availability – a key factor that can give companies a competitive edge, for example when three shifts are worked. But not only the technical development has been a factor; the drop in the price of robots by more than 50 percent since 1985 has made a major contribution to their final breakthrough in the assembly area. The lower unit price has been made possible by a reduction in the number of robot parts, improvements to the robot manufacturing processes, and the lower costs that became possible as larger numbers of units entered the market.

Robotized cylinder head assembly at Audi in Györ

ABB Flexible Automation GmbH of Langenfeld, Germany, was contracted to design and install Europe's first robotized assembly plant for multivalve cylinder heads for *Audi Hungaria Kft* in Györ, Hungary. Just half a year lay between the conceptual design phase and the installation and commissioning of the highly flexible plant.

Audi has been producing a new line of cylinder heads **1** for its new generation of engines – straight 4 and V6 cylinder units employing multivalve technology – for the A4 and A6 models (*Table 2*) since 1994. Thanks to Audi's engine family concept,



Multivalve cylinder head for an Audi car engine on the robotized assembly line at Györ, Hungary **1**

Table 1:
Development of robot technology in the years between 1985 and 1995

Handling capacity	+ 50 %
Speed	+ 40 %
Work envelope	+ 20 %
Price	more than 50% lower
Reduction in no of parts	from 100 to 35
Availability	from 5,000 to 40,000 h MTBF*)

*) *M*ean *T*ime *B*etween *F*ailures

Table 2:
Cylinder head data

Engine type	Engine capacity	Engine	No of valves
Straight 4	1.8 l	NAE*) TE	20
V6	2.8 l	NAE	LHS and RHS cylinder heads with 15 valves each

*) NAE = Naturally aspirated engine TE = Turbocharged engine

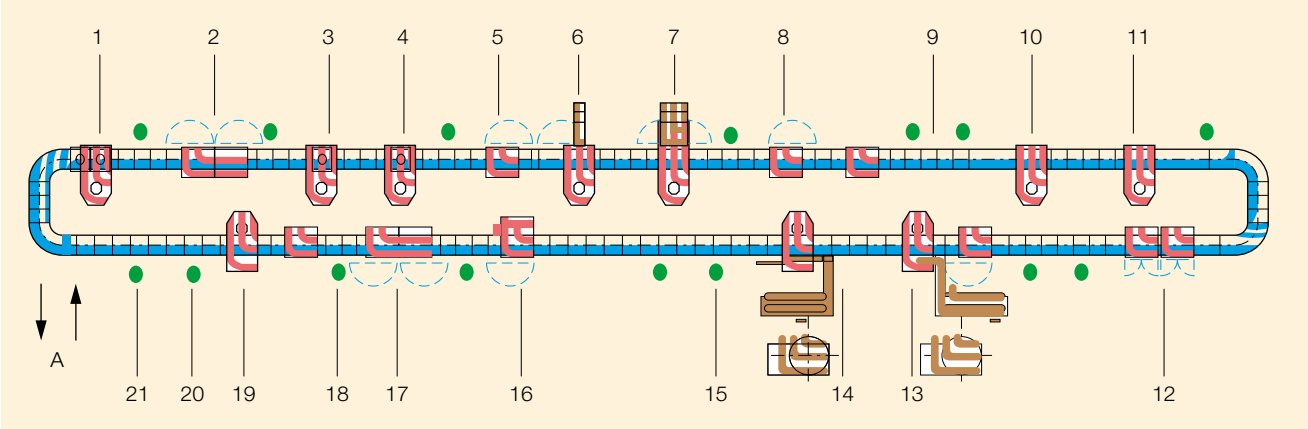
other versions of the engines can easily be produced without having to make costly changes to the plant.

The assembly plant was designed and built in close cooperation with the customer and employing 'simultaneous engineering' principles. Tools used to plan the project included simulation software and advanced test facilities. As part of the product development programme, the cylinder head parts were designed for low-cost, automatic assembly. The result is an assembly line which is custom-built for the new cylinder head technology **2**.

A combination of conventional, manual and robotized stations ensures adherence to the customer's stringent quality requirements. The concept further allowed planning, realization and commissioning of the plant in the shortest possible time, while guaranteeing maximum operating flexibility and availability. As a result, the cylinder head assembly plant in Györ can be counted among the most modern in the world. Initially designed to operate with a cycle time of 40 s for a production rate of 320,000 units per year, it is currently being upgraded to allow a cycle time of 23 s, which will increase the capacity to 500,000 cylinder heads a year. The cost to the customer of this upgrade is not high, since contingencies had already been made for it during the initial planning. The assembly line, which is 50 m long and 10 m wide, requires no extra space in order to cope with the increased capacity.

Multifunctional robots

The Györ plant has a total of six robot stations designed for a range of high-precision assembly tasks. Some of the robots are multifunctional, meaning that they perform different operations. ABB jointed-arm robots fit the water-cavity lock covers and mount the valve stem seals, valves and valve spring cotters in the cylinder heads. Also robotized is the fitting of the tappets and shaft sealing rings. In addition to the actual assembly, the robots perform sev-

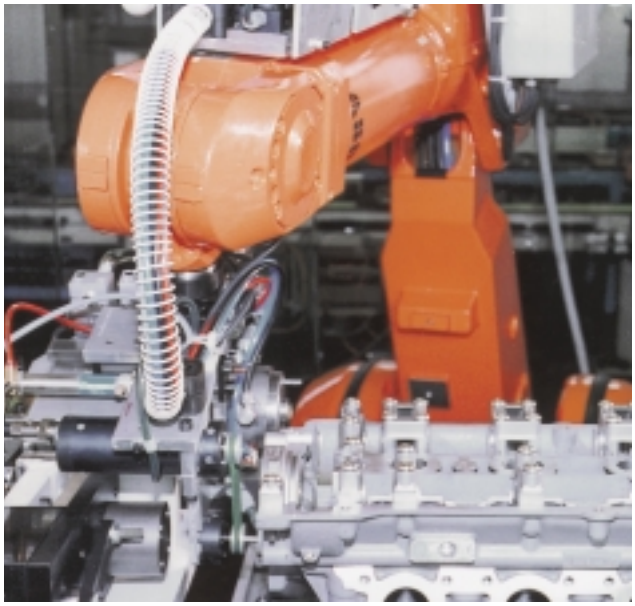


Configuration of the robotized assembly line for multivalve cylinder heads **2**

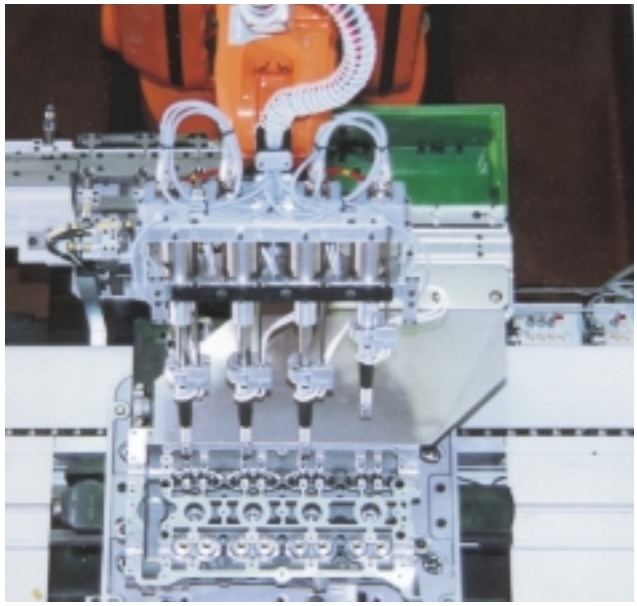
Green *Manual workstations*
Red *Assembly operations with ABB jointed-arm robots and conventional automated stations*

Operations

1 *Lock cover assembly: bore lubricated, cover pressed into place and seal checked*
2 *Bearing cover removed and placed on pallet*
3 *Valve shaft seal lubricated, checked, fitted*
4 *Duplicate of 3 for extended line with cycle time of 23 s*
5 *Cylinder head turned through 180°*
6 *Duplicate of 7 for extended line with cycle time of 23 s*
7 *Valves fitted*
8 *Cylinder head turned trough 180°*
9 *Valve disks/springs fitted*
10 *Duplicate of 11 for extended line with cycle time of 23 s*
11 *Valve spring cotters placed in position, laser check*
12 *Check, tappet bores lubricated*
13 *Tappets fitted*
14 *Duplicate of 13 for extended line with cycle time of 23 s*
15 *Camshaft fitted*
16 *Sealant applied, bearing surface lubricated*
17 *Camshaft bearing cover positioned and fixed in place (torque/angle of rotation)*
18 *Camshaft turned to top dead-point*
19 *Sealing ring and lock cover fitted*
20 *Hall sensor fitted*
21 *Final check and approval of cylinder head*



Automated lock cover assembly **3**
The lock cover of the water cavity is fetched by an ABB robot, which fits it into the cylinder head.
A controlled amount of sealant is sprayed into the bore.
Hydropneumatic cylinders press the cover into position, the robot monitoring the applied pressure.
Afterwards, the robot checks for tightness.



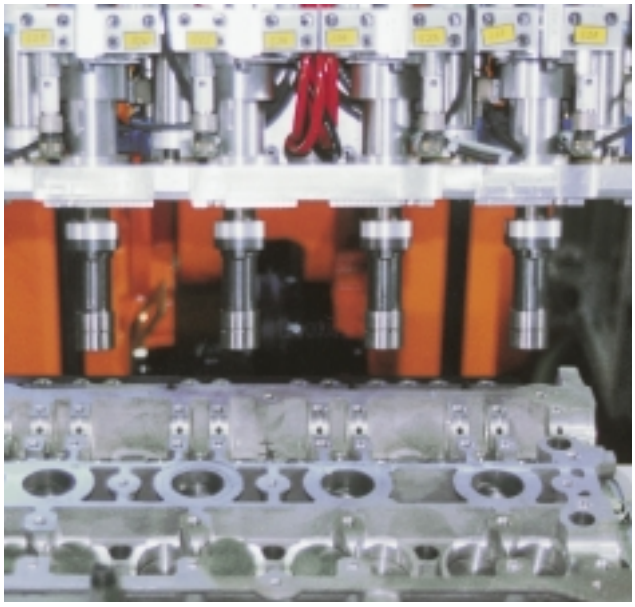
Assembly of the valve shaft seal **4**
Five cycles are needed for the robot to fit four valve shaft seals in the cylinder head.
Each of the robot tool's probes checks for minimum/maximum force during the assembly operation.
Tests carried out afterwards include a check that the sealing springs are in place.

Valve assembly **5**
This robot is programmed to fit four (inlet and outlet) valves. The robot takes the valves from two pallet-type magazines, aligns them and inserts them with high precision into a valve guide just 8 hundredths of a millimeter larger than the valves. A camera system checks that the valves are mounted in the correct positions.

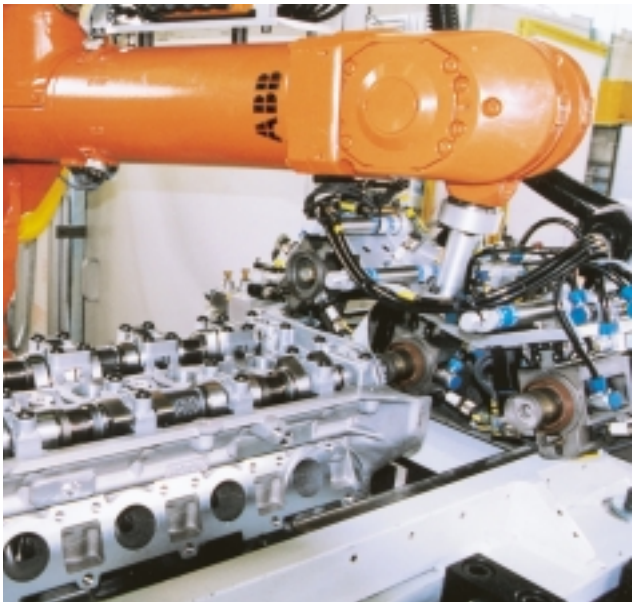
Assembly of the valve spring cotters **6**
After the valve springs and disks have been assembled manually, sets of four valve spring cotter pairs are fitted by the robot. The robot tool is equipped with one cylinder per pair, which it uses to press the valve springs into position. An automatic check is carried out to ensure that the cotters are in place.

eral checks and test functions; for example, they check the lock-cover seal and that the valve spring cotters are in place, plus the level of oil in the tappets. Defective parts are identified and removed by the robots (**3** to **8**).

In addition to the robots, Audi's new assembly line has six conventional automated stations for tasks such as loosening



Assembling the tappets **7**
Differences in diameter are no problem for the robots that fit the inlet and exhaust tappets. Special assembly motions allow four tappets to be fitted simultaneously into four bores with diameters just six hundredths of a millimeter larger than those of the tappets.



Assembling the shaft sealing ring **8**
A robot mounts two shaft rings and a lock cover at different locations on the cylinder head.
Defective items are identified and removed.

the camshaft bearing caps, turning the cylinder head, checking for unwanted parts and bolting the bearing covers in place 9. These tasks involve operations which can be carried out cost-effectively using conventional equipment. During the design of the plant, priority was given to combining the robot stations, conventional stations and manual workstations in a way that would guarantee maximum economy.

Automation was dispensed with for certain operations, for example picking up and putting down the cylinder head, fitting the valve springs and spring plates, positioning the camshaft and checking the camshaft friction. Each of these operations can be carried out cost-effectively by manual means 10. These tasks can also be automated later, if required.

Special features of the assembly line

The exceptional flexibility of the plant allows easy adaptation to changing conditions or requirements. Another advantage is the ease with which the assembly line can be extended. Among the special features of the line is that it allows the customer to reduce batch sizes for three or four of the cylinder head models to 'one-off' without time-consuming retooling. The concept devised by ABB for the line focuses on 'lean' operation; for example, no facility has been provided for the costly and unnecessary transfer of workpieces away from the line for repairs. Checking of the assembly process itself takes place in-line. Workpieces found to be not in order (NIO) as well as defects are signalled and removed immediately from the line.

The entire line is controlled with the help of two programmable controllers. For each of these there is a central control desk where the status of the assembly line can be displayed and controlled. One of the two controllers also manages the job orders. Also integrated is a system for counting the workpieces and for preparing the IO/NIO statistics. The distributed control configuration does away with bulky control cubicles. Reliable data transmission is ensured by a system bus (Phoenix Interbus-S), which has allowed the plant-wide wiring to be reduced to a minimum. This also contributed substantially to a reduction in the assembly time and cost of the plant.

High-performance ABB transport system

ABB's proven, modular transport system carries the cylinder heads, which weigh 15 kg each, from station to station 11. The weight of the pallets on which the cylinder heads lie can total as much as 300 dN. All of the system components are easily accessible and can be assembled or dismantled from above.

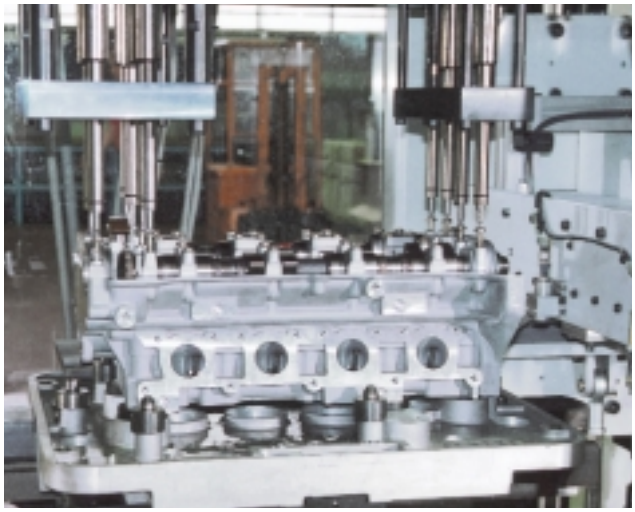
Benefits offered by the transport system include:

- Highest availability
- Ergonomic design and safety features
- Good cost/performance ratio
- Reliable pallet transport
- Minimal spare-parts inventory
- No maintenance
- Minimal noise

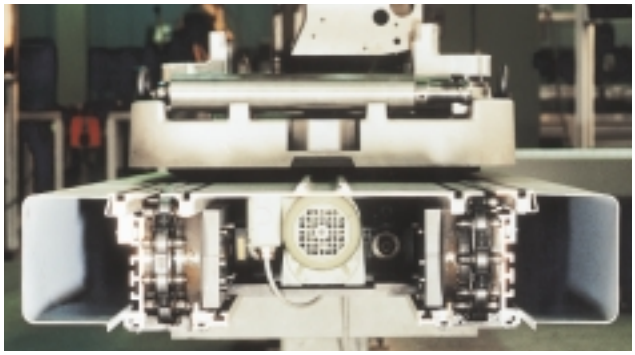
A mobile coding system is provided in which the data for each pallet are integrated. Stored in this system are, among other things, the production data, important information about the cylinder head, and the assembly status. The apparatus for scanning the pallets is integrated in the transport system.

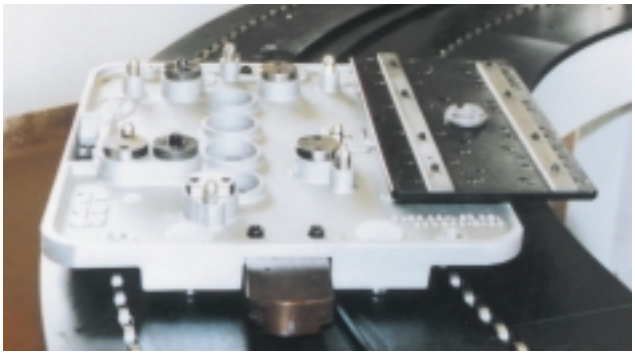
Positioning and fastening of the bearing cover 9

A gripper in a conventional automated station picks up the camshaft bearing cap and positions it above the camshaft. Afterwards, the bearing caps are bolted in position, the camshafts being pressed down at the same time.



Manual assembly of studs 10





Modular transport system for the 15-kg heavy cylinder heads 11

a *Section through the transport system*

b *Transport system with pallets*

Maintenance is kept simple

A new, patented safety barrier replaces the conventional mesh-wire barriers found in most assembly plants. Made of transparent, high-strength Macrolon, it offers operators an uninterrupted view of all the important parts of the plant and the assembly process. It can also be easily removed. Mobile, transparent safety barriers surround the cells in which the robots work. Easy access for maintenance and service work is provided to all of the stations and robots 12. The open station configuration facilitates ease of maintenance and trouble-shooting with the production line still running.

Problems related to one of the assembly tasks can be corrected by direct intervention at the respective machine. Easy access is provided by both hinged and sliding doors. During longer disturbances, workpieces can be transferred to a standby workstation.

Benefits of industrial robots

Multifunctional, six-axis jointed-arm robots from ABB have demonstrated in recent years that they are ideal automation tools for applications in the automotive industry. They are outstandingly well-suited, for example, for turnkey automation systems which have to be up and running in a very short time. Features that speak for ABB robots are the reduced time needed for project engineering, the minimal operator training that is required, and the speed with which they can be installed and taken into operation. ABB industrial robots are moreover highly flexible – a feature that underlines their suitability for 'simultaneous engineering' projects, in which changes can be undertaken even in the later stages of product development. Often, only the control software of the robots has to be modified. Used as a standardized automation tool, today's industrial robots exhibit almost 100 percent availability and can therefore contribute significantly to higher availability for the overall production facility. Extra bonuses offered by modern industrial robots are low maintenance and service costs plus minimal spare parts inventories. Industrial robots are also often more cost-efficient than special-purpose automation systems, which are expensive to design and install. With a total of 50,000 units now installed, ABB is the world's leading supplier of robots. In 1995 alone, ABB installed 7,200 units worldwide.

All the stations are easily accessible for maintenance and service work. The transparent enclosure, made of high-strength Macrolon, gives operators an uninterrupted view of all the key parts of the installation and the assembly process. 12

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