In an auto body assembly line, parts such as the roof, doors and hatchback need to be accurately placed in position before assembly. These operations, which come after the framing station and re-spot stations, require robot path adjustment technology when the parts are positioned differently in each cycle. Five steps are involved in this process:

- **Auto body position measurement**, in which the measurement paths are determined at different locations on the auto body.
- **Profile analysis** to find particular points on the shape.
- **Sensor offset calculation**, based on a comparison of the measurements and the reference profile position acquired in a preliminary ‘learning phase’.
- **Definition of a new robot position for assembly**, here the sensor offsets are sent to the correlation matrix software to find the correct robot path for the assembly operation.
- **Part placement**

    Simply put, robot path adjustment is a technology that ensures the accurate placement of components by a robot. With the help of FlexPlace, smart and efficient robots will replace the heavy machinery that has been used until now.

**FlexPlace**

**A better solution for robot path adjustment**

ABB developed FlexPlace to more accurately and more efficiently measure and place parts with a robot. The FlexPlace workstation consists of Windows NT/2000 software for data processing, a PC with an acquisition board, a set of sensors mounted on the robot gripper, a connection for sensor cabling, and a mastering tool.

The sensors are used to define the shape of the part (either by a robot or linear motion unit). The acquired shape and a previously stored reference shape are then compared to obtain a two-dimensional (2D) offset, which is used as input in a correlation matrix to compute the robot path adjustment. The matrix parameters are experimentally built up from successive robot positions. This is the so-called ‘learning phase’, and is automatically performed by FlexPlace.
Robot path adjustment takes place in five steps.

**Step 1**  
Measurement of auto body position. Definition of measurement paths by moving gripper to different locations.

**Step 2**  
Profile analysis to find particular points on shape.

**Step 3**  
Sensor offset calculation based on comparison of measured and reference profile positions acquired in a preliminary learning phase.

**Step 4**  
Definition of new path positions. Sensor offsets are sent to correlation matrix to find correct robot path for assembly operation.

**Step 5**  
Part placement.
How FlexPlace works
At the moment, FlexPlace is designed for body-in-white (BIW) operations, for example to place the roof, doors and hatchback or any other subassembly that needs placement relative to the position of the auto body. It goes without saying that FlexPlace can, of course, also be used for applications other than BIW. For example, it can be very useful for the placement of final assembly parts like seats, fenders, bumpers, front units and trim mounting, or to position the windshield on a vehicle. The same software can be used in each of these cases – in combination with a different type of sensor to allow customers to take measurements on a painted auto body.

“FlexPlace solves significant customer problems in automobile body production,” says Francois Malatier, R&D manager at ABB’s body-in-white facility in France. “By handling the robotic positioning of parts to be assembled on the auto body, it enables our customers to avoid the heavy tooling and machinery problems and costs associated with such assembly. FlexPlace is an outstanding technical solution and a significant achievement for ABB. It is an intelligent combination of sensor adaptation, pattern recognition software and matching software, packaged into one user-friendly product.”

FlexPlace versus absolute path adjustment
Two different approaches to robot path adjustment are in evidence today: absolute and relative path adjustment (see Glossary). After benchmarking the different solutions and evaluating customers’ feedback and needs, ABB chose the latter approach and one-dimensional optical laser (range finder) type sensors for FlexPlace. The sensors are connected to the acquisition board via a 4–20 mA current loop signal, which is less sensitive to electromagnetic disturbances. A digital output from the robot controller...
synchronizes the measuring path and the acquisition board. The path adjustment values for the placing cycle is transmitted by an Ethernet link (ABB Interlink). This link is also used to synchronize the robot movement with the PC program.

With FlexPlace, a vehicle roof can be measured and placed in its designated position in about 10 seconds with an accuracy greater than +/- 0.5 mm. The high reliability of the tool is mainly due to the type of sensor ABB has chosen, the small number of components and the reduced environmental sensitivity. The set-up and production phases are user-friendly. The graphic user interface is intuitive and provides direct access to the different application screens.

Francois Malatier says FlexPlace is a solution that is primarily based on innovative software: “Our competitors solve this problem in different ways. Some use simple sensors and software, some use fixed cameras. The investment cost for such technology is very high – the system needs several sets of cameras if several auto models are assembled on the same line. Our solution is mainly a software product development. We explored the possibility of using partners, but decided on internal development. We had to develop very ‘near-vision’ software, but it didn’t prove too difficult, thanks to our methodical approach and the young, forward-looking engineers in the team.”

**Functional and efficient**

As already mentioned, the system’s high reliability is due in large part to the very accurate and proven one-dimensional (1D) laser sensors. To measure the auto body profile, the sensors are moved either by the robot (the sensors are mounted on the gripper) or by a small built-in shuttle unit. The product is anything
but a ‘black box’, since the man-
machine interface gives the user access
to all the parameters. In addition,
built-in process control functions
make it easy for the customer to
verify or diagnose any trouble or
faults.

**FlexPlace outperforms fixed sensors**

Compared with absolute path adjust-
ment, in which fixed sensors are used,
FlexPlace offers a more efficient
solution at almost every process stage
and for every critical process factor.

One innovation is the utilization of off-
line calibration on a mastering fixture
in the assembly station. And, the initial
calibration phase takes account of
robot arm geometry default. By
comparison, absolute path adjustment
requires the use of a ‘gold model’ and a
coordinate measurement machine
(CMM) in another station.

With FlexPlace there is no risk of the

sensors disturbing each other because
of their close proximity to the
measured area. Neither are they as
affected as cameras by flashing lights or
similar interference in the workshop.

FlexPlace’s optical laser sensors do not
make contact with the part, so users
have considerable flexibility when
choosing the auto body position to be
measured for reference. By comparison,
the fixed sensors in absolute path
adjustment are further away from the
measured area, so there is a high risk
of interference. Fixed sensors are also
more dependent on environmental
conditions and make the simultaneous
acquisition of measurements more
difficult.

The new system makes a more
flexible and adaptable layout possible.
All that is needed to fit the sensors is
some adaptation of the gripper. This is
another advantage FlexPlace has over
absolute path adjustment, which has
inherent layout constraints. Most

significantly, a steel structure must be
designed and constructed to position
and hold the sensors. The simpler
sensors and intuitive software used
with FlexPlace make the new solution
less expensive. FlexPlace ‘thinks for
itself’ and requires less costly
infrastructure, preparation and
maintenance. With the more complex
fixed sensor method, an external
supplier often has to be brought in for
the calibration and highly qualified
operators are needed to monitor the
installation.

Of course, there is a higher risk of
damage to the sensors used in
FlexPlace because they are mounted on
the gripper and exposed to shock and
vibration. (In absolute path adjustment
the sensors are mounted outside the
working area of the moving
equipment.) However, the modular
FlexPlace sensors can be easily and
quickly replaced using the mastering
fixture in the station. (Replacement of
absolute path adjustment sensors is complicated and time-consuming because the replacement sensors have to be calibrated with a CMM or laser measuring system.)

System checks and quality control are also easier with FlexPlace; placing the mastering fixture in the station allows the user to check the system whenever necessary. With absolute path adjustment, on the other hand, after the auto body has been measured the system has to wait until it has been in the check station before confirming the result.

With FlexPlace, any robot inaccuracy due to temperature change can be automatically compensated because the sensors are mounted directly on the robot. Absolute path adjustment requires an accurate robot model and a fixed reference in the station for this kind of compensation. Unlike absolute path adjustment, in which the location of each sensor must be accurately determined within the assembly station, the new solution considers all the defaults in the measurement chain.

**Glossary**

**Absolute path adjustment**
This is based on measurements of the auto body location with sensors mounted on a rigid structure in the station. The part and the robot positions are determined and the placing path is defined in the auto frame. Using these two absolute positions, the computer defines the relative offset to apply to the auto frame for assembly.

**Relative path adjustment**
Sensors are mounted on the robot gripper. The robot moves the sensors in front of the auto body, and the recorded profiles are processed to find the body position. For the ‘learning phase’, the reference vehicle is placed in the station and the known offset values are applied to the robot. The sensor values are registered for each position. At the end of this process, the system has learned the sensor responses to vehicle displacement, and this information is entered in the correlation matrix, which defines the correct robot positions.

**Gold Model**
An auto body manufactured especially to reduce geometrical variations. It is used to establish reference measurements in absolute path adjustment.

**CMM (Coordinate Measurement Machine)**
A machine designed for auto body or tooling measurements. It is used to measure the auto body Gold Model in absolute path adjustment.

**Mastering Fixture**
A tool mounted in the assembly station, used for initial calibration of the sensors and adjustments after a sensor replacement.

**Body-in-white**
The part of the auto manufacturing process that takes stamped parts and produces an assembled body shell complete with closures. At the end of this manufacturing step, the body is ready for surface treatment and painting, and the shining sheet metal looks almost white in color.

**Correlation matrix**
A mathematical template that changes the sensor offsets into robot position offsets. It contains coefficients that are determined from data collected during the learning phase, when the robot positions are changed and sensor offsets are recorded for each of the robot positions.