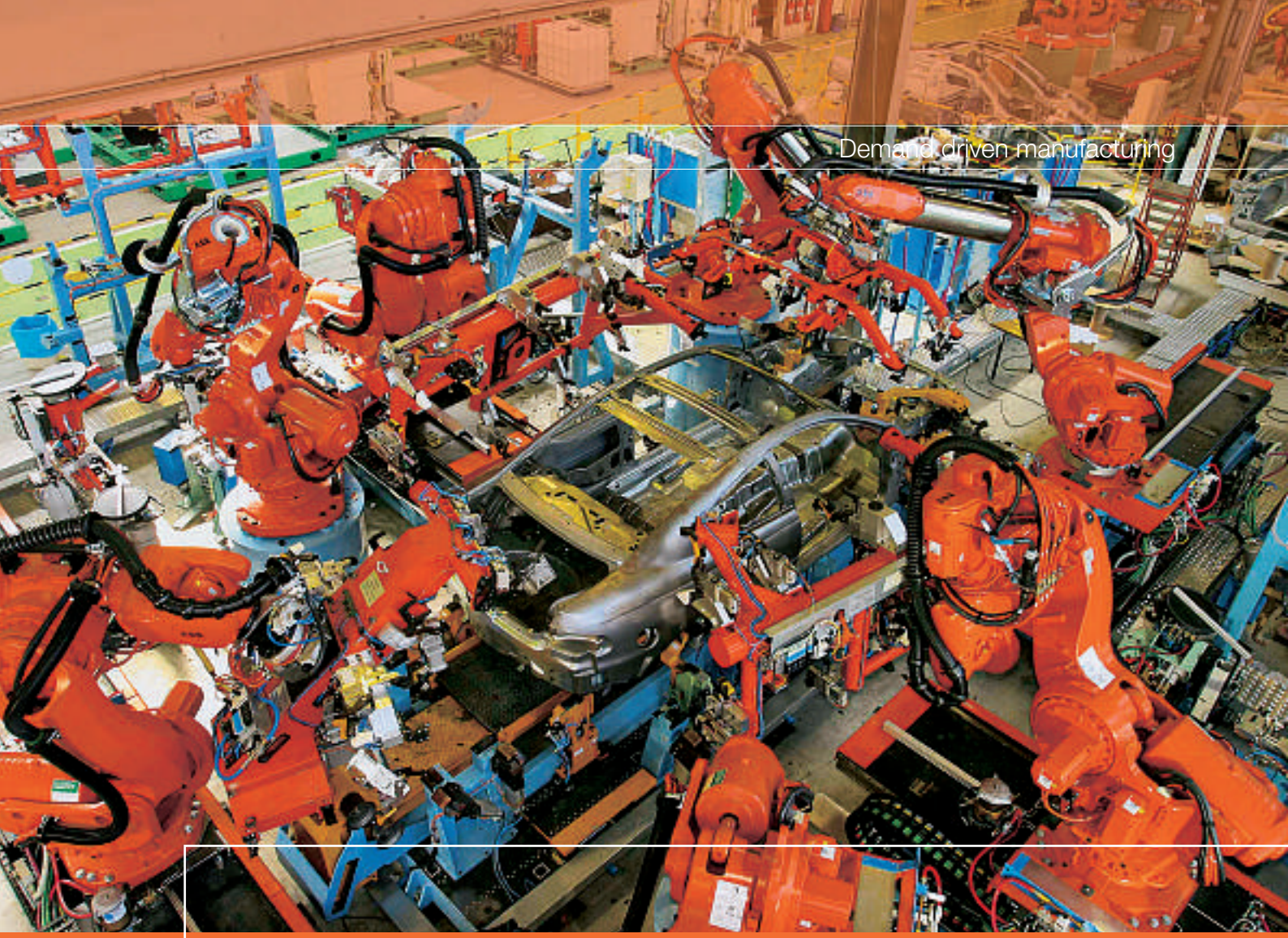


Spot on

Accurate spot welds with equalizing software

Lennart Sundstedt, Christian Müller, Åke Olofsson

When a spotwelding gun homes in to its target, a precise control of its position and pressure is vital. Such a control system must compensate for the gun arm deflection under the effects of the pressure it applies. The electrode tips (one on either size of the sheet) must contact the sheet at precisely the same moment to prevent bending of the sheet. Once in the right position they must apply the right pressure to weld, again, without deforming the sheet. Additionally, the wear of the electrodes must be taken into account.

In the past, mechanical equalizing systems based on pneumatics were used. ABB's servo-controlled *Software Equalizing* breaks new ground by offering far greater accuracy and flexibility leading to higher weld quality – and that while reducing the need for maintenance.

ABB Robotics provides flexible software solutions for various spotwelding applications. Dedicated software options exist for welding with pneumatic as well as with servo guns. *RobotWare Spot Servo* is a software package for welding with servo guns. It shares a common controller and internal motion control logic for controlling the gun's servomotor and the six axes of the robot. Hence, no external drive control unit is required and the control of the servo gun is fully synchronized with the movements of the robot.

As a further development, ABB Robotics is now introducing *Software Equalizing*, a motion-control software that replaces the conventional mechanical (pneumatically or electrically controlled) equalizing equipment mounted on spotwelding guns. *Software Equalizing* reduces the cost of equipment, reduces the need for maintenance and provides a higher weld quality.

A spot of history

Industrial robots entered the spotwelding scene more than thirty years ago. At the time, the accuracy of robots, fixtures, clamping devices and welding guns was poor. These inaccuracies were overcome by deploying mechanical equalizing devices, 1, making the gun flexible when closing the gun and building up the force in the tips prior to commencing the weld.

Over the years, robots have become more accurate and tolerances in metal sheets and clamping devices have been reduced. Servo controlled spotwelding guns are replacing pneumatic guns. As a result, the positioning accuracy of the sheet metal, and the repeatability of robot actions are so high that their variations show practically no influence on the spotwelding result.

There are, however, still other inaccuracies and effects during the spotwelding sequence that influence the weld quality. These include:
- Deflection of the fixed gun arm
- Inaccuracies in programming
- Tip wear.

Unless these are adequately compensated, the metal sheets can bend, warp or be damaged during welding. Failure to achieve the programmed squeeze force in the metal sheet can cause poor weld quality and residual strain in the metal. There is still need for an equalizing solution.

ABB Robotics is now introducing Software Equalizing, a motion-control software that replaces the conventional mechanical (pneumatically or electrically controlled) equalizing equipment mounted on spotwelding guns.

Software Equalizing

A typical spotwelding cycle is depicted in 2. In 2a, an IRB6600 robot with open gun approaches the weld position. The gun is closed 2b 2c at the weld position. Force is built up in the gun, ie, deflection takes place (force control replaces position control). When the force has been built up, the gun is closed and spotwelding takes place. Force in the gun arm is released, the gun opens and the robot moves the gun to the next position 2d (switching from force control back to position control).

ABB Robotics' *Software Equalizing* replaces the traditional mechanical equalizer with a package of easy to use functions that reduce costs (simpler guns, less maintenance, no compressed air to the gun) and makes programming as well as operation easier and faster. Features include:
- Gun arm deflection compensation
- Teaching support
- Tip wear monitoring and compensation
- Automatic release of fixed gun arm.

These functions are discussed below.

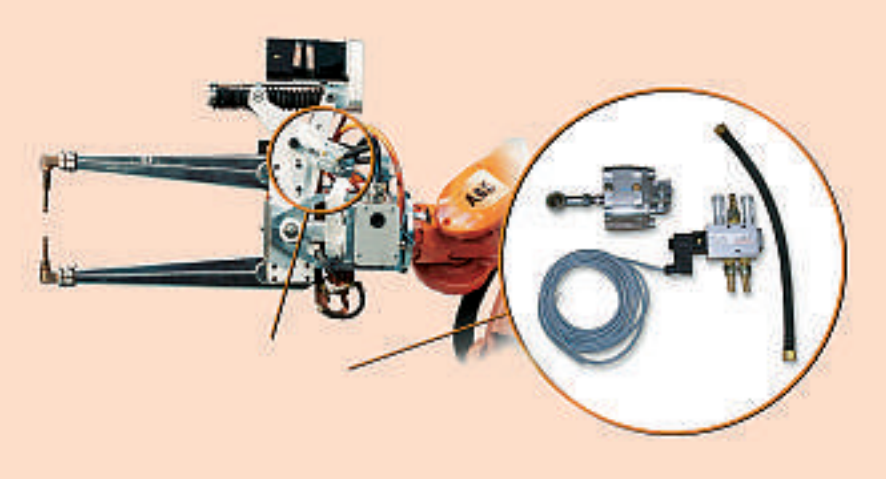
Gun arm deflection compensation

When the spotwelding gun closes to commence welding, the fixed gun arm will inevitably bend on account of the applied force. As a result, the position of the weld is inaccurate. To compensate for this bending, and to obtain the programmed squeeze force in the metal sheets, the gun position has to be corrected. This was previously achieved through mechanical equalizing.

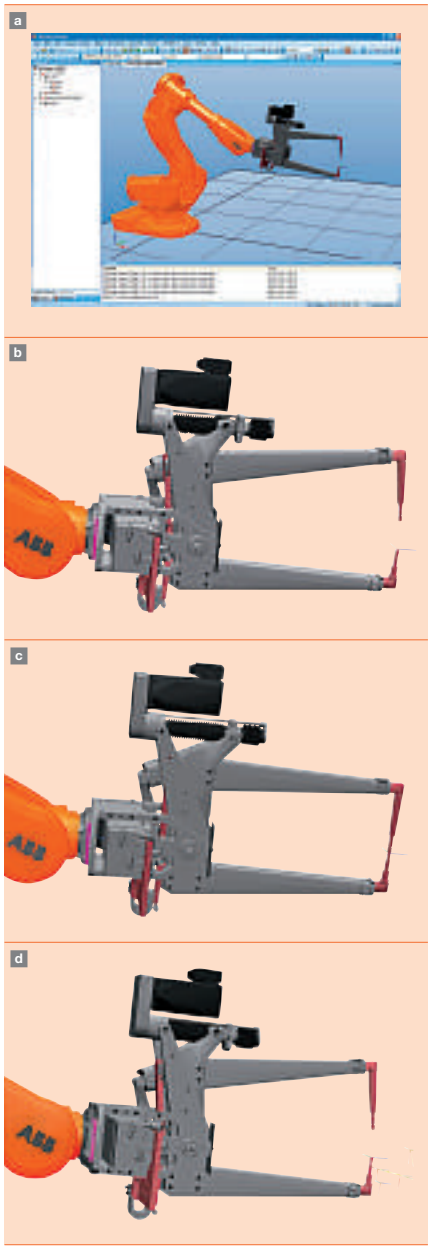
To replace this mechanical equalizing functionality by software means introducing additional movements of the fixed gun arm, either by acting on the gun itself (which then needs an additional gun axis), or on the six axis of the robot. ABB's approach uses the existing motion control software of the robot to achieve these movements. The internal motion control software fully coordinates the compensating movements of the robot with the force build-up in the gun. The same occurs when the force decreases after welding.

Detailed studies and measurements show that when *Software Equalizing*

1 A servo gun with a mechanical equalizer; such equipment was common prior to the introduction of *Software Equalizing*



2 Views of a typical spotwelding cycle, created with ABB's RobotStudio software



3 Flexpendant in *"Weld positionTouch Up"* mode

is used, there is no bending of the metal sheet prior to or during welding. There is no other force present than the squeeze force applied in the gun tip. The compensating movements can also be perfectly synchronised with the movement of the gun during the force control phase. This means that welding is performed with practically no stress or strain in the metal sheets and the weld quality is consequently improved.

Since ABB's solution uses internal motion control logic and software to adjust the position of the fixed gun arm tip, the behaviour remains identical, regardless of gun orientation. As a comparison, a mechanical equalizer usually provides different gun arm deflection compensations for different gun orientations. A gun that works well when it closes in a horizontal position, might fail to compensate adequately in a vertical position. Tuning and trimming of the gun for good compensation in all orientations can be a tedious and time-consuming task.

By using the internal motion control logic and the robot to adjust the position of the fixed gun arm tip, ideal synchronization with identical behaviour, regardless of gun orientation, is allowed.

The gun arm deflection compensation functionality works for both X-type and C-type[1)] servo guns and in the same way for both robot carried guns and stationary guns. The only gun specific information that must additionally be provided is the deflection characteristic (gun arm deflection as a function of force and time). Such facts are usually available in the gun's datasheet.

Footnotes

[1)] The term "X-type" is applied to welding guns of scissor configuration (electrodes perpendicular to gun arm as in 2) and "C-type" to direct-acting configuration (electrodes in axis of gun arm, with one electrode in the direct continuation of this arm and the other attached via a C-shaped bracket).

Teaching support

Accurate programming of spotwelding positions is a prerequisite for good welding quality. The use of *Software Equalizing* increases the need for precise programming of positions. ABB Robotics software now includes a feature called *Weld-position Touch up*, making it easy to fine-tune programmed positions.

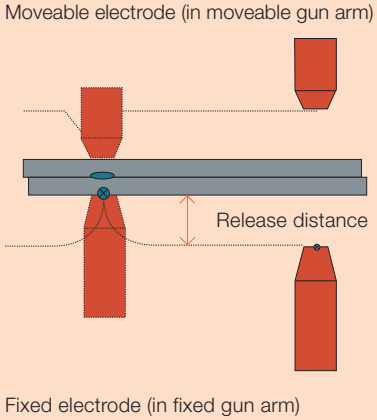
Weld position Touch Up is a function provided in manual mode (ie, during programming or updating of the program). In touch-up mode 3, all programmed instructions (except welding) are executed as normal. Each time the robot reaches a weld position in the program, it stops at the welding position and a touch-up dialogue appears on the FlexPendant Textbox.

The position of the fixed and movable gun arm tips can be incrementally adjusted using a single soft button on the FlexPendant. The position of the fixed gun tip is moved towards or

FlexPendant

The FlexPendant 3 is ABB's handheld robot-user interface device. The ergonomic device designed for use with ABB's IRC5 controller weighs less than 1.3 kg and has a color touch-screen and a user friendly interface.

4 The electrode tips are withdrawn to a predefined release distance to prevent scratching of the sheet during movement



away from the metal sheets in predefined (adjustable) increments.

Tip wear monitoring and compensation

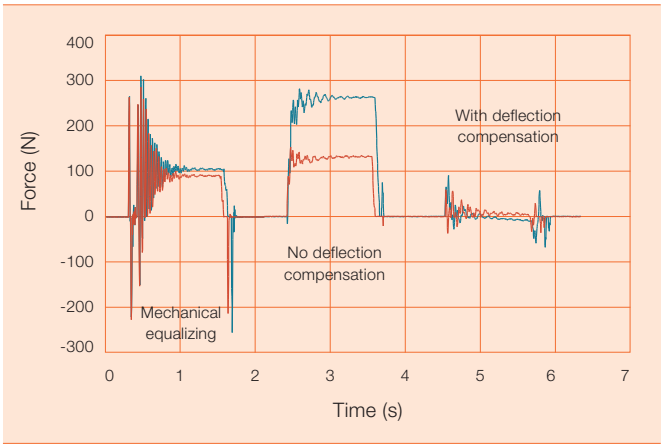
Spotwelding tips (electrodes) are continually worn down through use. As a result, the actual positions to which the gun is moved prior to welding must be adjusted for this wear. *Software Equalizing* incorporates a user-friendly tip-wear measurement and compensation functionality.

The total wear on both tips is determined by closing the gun "in the air" (without sheet) at a predefined force. The difference in the closed position of the gun is then measured, and this value is used to adjust the gun stroke. This guarantees constant gun closing times (and thus constant cycle times) as well as constant weld forces.

To simplify programming of spot welds as much as possible for the user, the robot automatically moves the fixed gun arm a pre-programmed distance perpendicularly away from the sheet while opening the gun.

Tip wear on the fixed tip can be calculated either over the expected relation between its wear and the total tip wear, or can be measured with the help of a fixed reference plate and a special "move"-instruction. For robot-carried guns, the reference plate is fixed in the working area of the robot. The actual position of the fixed gun arm tip is identified with a search-function, moving the tip towards the reference plate until a defined force is reached. In case of stationary servo guns the reference plate is mounted on the robot's gripper instead and the robot moves it towards the fixed tip of the gun. Because the robot itself is the measuring device, no additional equipment is needed.

5 Force in metal sheet for welding forces of 1.5 + 3.5 kN



This functionality not only provides accurate tip wear data, but also enables automatic tip wear supervision. Alarms can be set for critical cases, eg, when tips require dressing, replacement or have been lost.

Other methods, such as a light beam, can also be used for measuring tip wear.

Automatic release of fixed gun arm

When guns with mechanical equalizing systems are used, the fixed gun arm tip is automatically released from the sheet on opening the gun. Using *Software Equalizing*, an extra robot movement is required to release the fixed gun tip from the sheet. This is to prevent the tip from scratching the metal sheet while moving to the next weld position.

To simplify programming of spot welds as much as possible for the user the robot automatically moves the fixed gun arm a pre-programmed distance perpendicularly away from the sheet while opening the gun. The release movement can be directly followed by a corner zone and the next "move"-instruction to another area. The release distance 4 is set by the user and can be defined individually for every gun.

Verification of *Software Equalizing*

Functionality and performance have been thoroughly verified by force and high speed video measurements on various gun brands as well as for all ABB spotwelding robot types. For the measurements shown in 5 and 6, a standard ABB X-gun of type SRT-M-E mounted on an IRB6600/225 robot was used. The throat depth of this gun is 645 mm and the maximum weld force is 3.5 kN. The deflection is then 4.7 mm.

The force measurements were performed with a very stiff metal sheet mounted on a standard force sensor. The setup permitted measurement of the force introduced in the sheet only perpendicular to its surface. This force bends and possibly even damages the sheet and should be compensated by the equalizing system.

As shown in 5, mechanical equalizing produces forces on the sheet mainly during the closing and the opening of the gun. These are the reaction forces from the inertia of the gun when the tips contact the sheet. The equalizing force that remains during welding is due to a slight gun imbalance in the weld position.

When no mechanical equalizing and no deflection compensation is used (weld position of the fixed tip directly on the sheet) the remaining force on the sheet depends on the weld force and thus on the deflection of the fixed gun arm. This shows how important a good compensation of the gun arm deflection is.

Functionality and performance have been thoroughly verified by force and high speed video measurements on various gun brands as well as for all ABB spotwelding robot types.

The results for *Software Equalizing* show that there is only a minimal perpendicular force on the sheet during the weld, and that this is independent of gun orientation and weld force.

The performance of *Software Equalizing* can also be shown by monitoring the bending of a very thin sheet (which requires almost no force) with a high speed camera 6. This test shows how accurately the deflection of the fixed gun arm is compensated during the force build up.

6 shows a sequence of pictures from the movement of the gun to the weld position, closing of the gun to sheet thickness and the force control with the build up of the weld force (3.5 kN). In this case the sheet thickness is about 1.0 mm.

6a shows the movement of the gun to the weld position and the closing of the gun. The fixed (lower) tip approaches the metal sheet to the predefined release distance (5 mm in this case) before moving to its weld position on the sheet. During this movement, the gun is closed synchronized with the robot movement to the sheet thickness. This ensures that both gun tips reach the sheet simultaneously, regardless of the programmed speed.

6b and 6c show the force control phase with the build up of the weld force. In both cases, the force control is identical and the same gun force (3.5 kN) is applied.

6b shows the behaviour of the setup without any effective mechanical equalizing. The gun used actually has an active mechanical equalizer, but since the metal sheet does not provide any reactive force, the mechanical equalizer fails to compensate the gun arm deflection.

6c shows the same sequence with *Software Equalizing* activated. In comparison to mechanical equalizing, the gun is held in position by deflection compensation. The deflection of the gun is exactly compensated throughout the force build-up phase and practically no movement of the metal sheet occurs. By eliminating this risk of bending or damaging the sheet, a high weld quality is attained.

The performance of ABB Robotics' *Software Equalizing* shows it can replace mechanical equalizers on servo guns and provide far higher deflection equalization.

Benefits

The performance of ABB Robotics' *Software Equalizing* shows it can replace mechanical equalizers on servo guns and provide far higher deflection equalization. A function to adjust for inaccuracies introduced during programming is available. The fixed gun arm deflection and tip wear are compensated for by software. *Software Equalizing* utilizes internal motion control to adjust the position of the spotwelding gun with the robot's six axes. No additional drive unit or other mechanical equipment is needed besides what the robot controller already provides.

The benefits include:

- No mechanical parts that can wear or jam. This in turn reduces the risk for, eg., tip stick.
- Less time to tune and trim the mechanical functionality.
- Reduced maintenance and higher availability.
- Simpler, lighter and thus cheaper guns.
- Compressed air no longer required by the spotwelding gun, leading to simpler dress packs and less equipment.
- No effect of gravity; behaviour is repeatable independently of gun orientation.
- Enhanced user friendliness because of programming support, automatic release of fixed gun arm, tip wear monitoring etc.

A patent is pending for parts of the *Software Equalizing* functionality.

More information about ABB's software for BiW (Body in White) applications can be found at www.abb.com/robotics.

6 High-speed camera pictures of gun closure

a Moving gun to weld position

b Force control without mechanical equalizing

c Force control with *Software Equalizing*

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