March 2009

DVS – DEUTSCHER VERBAND FÜR SCHWEISSEN UND VERWANDTE VERFAHREN E.V.

# Sensors for fully mechanised arc welding Instructions for utilisation

DVS Technical Bulletin DVS 0927-2

*Translation of the German edition from September 2008*

**Contents:**



## 1 Scope of application

The technical bulletin deals exclusively with sensors which, according to their working principle, can be utilised for fully mechanised arc welding (search for the start of the groove and/or groove tracking) and serve to position the electrode relative to the welding groove and, if necessary, to regulate the welding parameters. Part 1 of this technical bulletin includes a representation of the physical working principles of various sensors. Part 2 considers the areas of application of the sensor systems, gives instructions about the utilisation potential and the restrictions of the systems and is planned as an aid for selection.

Neither the direct quality monitoring of the executed weld nor any of the procedures suitable for this are included in the area of responsibility of the sensors under consideration here (DVS 0954 technical bulletin entitled "Welding data as an aid for quality assurance in the case of automatic gas-shielded metal-arc welding" which is under preparation).

## 2 Introduction

The areas of application of the sensors for fully mechanised arc welding are just as diverse as the utilisation field of the arc welding processes. In this case, the utilisation of sensor systems generally serves the objective of safeguarding the quality of the welded joint in an efficient and economically viable way.

In this respect, the successful utilisation of the sensor systems depends, in particular, on the analysis of the welding condition as well as on the requirements on the demanded function of the sensor. The influencing variables can be systematically divided into the categories:

- workpiece-related influences
- installation-related influences
- influences relating to measuring and regulation technology
- process-induced influences

Three sensor principles have become widespread in practical application:

- optical sensors
- tactile sensors
- arc sensors

The description of the measuring principles on which these systems are based is included in Part 1 of this technical bulletin. The practical applicability of the individual systems is now to be dealt with while taking account of the influences specified above. Since three sensor principles (the optical sensors, the tactile sensors and the arc sensor) have essentially gained acceptance in practical utilisation, this technical bulletin also primarily refers to their specifications.

## 3 Definition of terms

The collective term "sensors for arc welding" is understood to relate to devices which, as a constituent of a fully mechanised welding installation, detect information about the position and, if at all possible, also about the geometry of the weld to be executed on the workpiece and provide it in a form which is suitable for the regulation of the position of the welding torch and, if at all possible, of the welding process variables according to the requirements set on the welding task.

## 4 Workpiece-related influences

In the list of the workpiece-related influences, the accessibility describes not only the sensor's possibility of reaching a position which is needed for the measurement of the component but also the sensor's property of not impairing the accessibility of the welding torch to the welding point. With regard to the positional tolerances, a distinction should be made between deviations in the component position and deviations in the torch manipulation. The two variables are superimposed on each other and result in both translatory and rotatory deviations between the welding torch and the groove. In most cases, it is sufficient to determine and compensate for the translatory deviations. The geometrical tolerances relate to the variation in the groove geometry. In the simplest case, this may be the formation of a gap between the groove edges. However, edge misalignment, angular tilting and a



DVS, Technical Committee, Working Group "Arc Welding"

Orders to: DVS Media GmbH, P. O. Box 10 19 65, 40010 Düsseldorf, Germany, Phone: +49(0)211/1591-0, Telefax: +49(0)211/1591-150

lack of or inaccurate groove preparation also lead to an impermissible change in the groove geometry. The surface finish has an influence as an essential criterion for the sensor reliability and the sensor accuracy. The suitability of the sensors is assessed with different groove geometries and welding positions as well as with the application of different materials.

### 4.1 Accessibility

In most cases, the increasing complexity of the weld path also means that the welding head has decreasing accessibility to the component. In the simplest case, a straight-line joint between two components is only impaired by clamping elements. The positioning of the welding head is often restricted in the case of a three-dimensional groove path with small radii and corners. Clamping elements hinder the accessibility in addition. Moreover, the positioning of a sensor is limited correspondingly.

This basically results in the requirement to utilise sensors with the smallest possible construction size.

Optical and tactile sensors can measure internal corners to a limited extent only since they either do not reach the corner themselves or prevent the welding torch from reaching the corner.

In the case of external corners or external radii, the sensor must be guided in such a way that the groove remains visible at all times.

Sensor components may be destroyed in the event of an unintended collision between the workpiece and the sensor.

### 4.2 Positional tolerances

The positional tolerances which should be compensated for by a sensor constitute the superimposition of the positional tolerances of the workpiece on the guiding tolerances of the installation.

The positional tolerances of the workpiece result from the tolerance of the geometry and the inaccuracies of the clamping. In the case of complex components, this results in:

- deviations of the centre of the groove
- deviations of the start and end of the groove
- edge misalignment
- angular deviations
- gap width tolerances

Another factor is the possible thermal distortion during the processing of complex components by means of welding technology.

The deviations in the guiding accuracy of the installation have a superimposed effect and are dependent on the axis position. Torch positions protruding by far have higher deviations than stiff, short axis positions.

The total of these deviations should be detected and compensated for with the sensor. Since the measuring point and the joint do not coincide for optical and tactile sensors, further calibration is necessary. This is the balancing between the measuring point of the sensor and the TCP (tool centre point) of the welding head.

### 4.3 Geometrical tolerances

As already described, tolerances of the component geometry and of the component position also lead to a variation in the groove geometry.

The compensation for the tolerances of the groove geometry extends beyond the simple adjustment of the welding position. Adaptive process controls required for this purpose.

The simple approach of using the natural compensation capacity of the welding process is widespread, i. e. the welding process is carried out within a robust process window which covers the expected groove tolerances. The welding parameters are not adjusted.

However, it may make sense to adjust the welding parameters in individual cases with wide tolerances of the groove geometry. Sensors which supply unambiguous information about the geometrical deviation and allow the installation to be controlled with regard to the adjustment of the welding parameters are needed for the adaptive regulation of the welding parameters. In particular, the optical sensors which permit any possible adjustment of the weld volume when the groove cross-section is changed should be named here.

### 4.4 Surface finish

The surface finish of the components is relevant to all the sensors.

Optical sensor systems need surfaces which are as uniform as possible and cause only slight changes in the reflection behaviour. Any soiling of, rust on and damage to the surface impair the measuring accuracy, as does any reflection from the surface.

The functioning capacity of tactile sensors is also impaired not only by soiling but also by linear cutting burrs or welding spatter.

Surface coatings which have an effect on the stability of the arc (e. g. soiling, irregular coating, also corroded surfaces) impair the signal quality for arc sensors.

As a rule, technical surfaces which are suitable for welding in industrial fabrication also satisfy the requirements of the sensors. The influence on the sensor functionality must be checked in each individual case.

### 4.5 Groove geometries

With all three primarily utilised sensor principles (optical sensors, tactile sensors and arc sensors evaluating process parameters), the groove geometries must exhibit certain characteristics. In the case of the **arc sensors** (systems evaluating process parameters) there must be an unambiguous correlation between a change in the distance and the relevant position. In this respect, one essential aspect is that it is not typical to measure the groove geometry through the arc but instead the molten pool surface below the arc. As an approximation, it may be said that the measured values constitute an assessment of the change in the penetration profile which is covered by a molten layer with a low thickness.

As far as the **optical systems** are concerned, attention must be paid to the smallest possible resolution. The groove must exhibit unambiguous geometrical characteristics which can be precisely assigned within the resolution of the system. The butt joint with the smallest gap width and without any edge misalignment continues to be the most problematical case.

As far as the **tactile sensors** are concerned, a component edge to be scanned must also unambiguously refer to the groove position. This component edge to be scanned does not inevitably have to be the groove itself. The butt joint with a zero gap is often the most difficult case here as well.

### 4.6 Welding positions

Particularly in the event of welding out of position, the process window available for the compensation for component tolerances is smaller for arc welding. In most of these cases, the torch positioning is only corrected. Weaved welding torch manipulation is not yet supported by all the optical sensors.

### 4.7 Materials (aluminium and CrNi steel)

At present, the arc sensor equipment for the MIG welding of aluminium cannot yet be regarded as the state of the art. For TIG welding, the arc sensor equipment may be used with aluminium materials too. In the case of optical systems, consideration must be given to the material-induced reflection factor of the surface. To the greatest possible extent, tactile systems are independent of the selection of the material.