# "Weld Monitoring" in Arc Welding

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In the majority of common welding processes, the welding variables viz. arc voltage, wirefeed speed or current, travel speed and the torch to work distance are preset manually by the welder or supervisor. This presupposes that enough is known about the material and the process for all the many parameters to be preset to their optimum values. However, there are many factors like, geometry of the workpiece, inconsistent weld preparation and poor fitup, distortion arising from heating, especially in long seams etc., which call for substantial variations in the preset values of the parameters as welding progresses. Presently, all such corrections are carried out manually by the operator as per his visual observation of the weld zone. This approach calls for extensive skill on the part of the operator and does not ensure defect free welds.

For the above reasons, there is a pressing demand to relieve the operator the task of monitoring the welding cycle and to replace it by an automatic sensing system.

With the advent of high precision welding equipment based on transistor or thyristor controlled power sources and availability of reliable seam tracking and electronic sensing devices, automatic monitoring of the welding cycle as it progresses i. e. real-timecontrol is now possible. A variety of sensing methods and feeback control systems are being tried out to monitor as many parameters as feasible, keeping the total economics in mind. These include use of direct and indirect sensors, feedback controllers, pulsing techniques and the like.

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**Introduction :**

Interest in monitoring and automation stems from the need for higher productivity, greater reliability and better quality. Weld monitoring is a part of a larger and more complex problem of automation and automatic quality control. In general, "Weld Monitoring' refers to the use of instrumentation to give a warning of a change in welding conditions or quality. However, recently, this term is being used to denote control functions, either for tracking the weld seam or for automatic quality control.

Weld monitoring techniques, therefore, can be classified under two heads :

(a) Those which control the tracking or movement of the welding device.

(b) Automatic quality control system.

The tracking concept is quite straight forward and can be approached in a number of ways varying from self-guiding rollers to servo-control devices and fluidics. Monitoring the quality of a fusion weld on the other hand, is a task of a extraordinary difficulty. The defects which can occur are numerous and it is often difficult enough even to identify them. Even if sensing methods could be developed which would detect the defects as they form, it would still be virtually impossible to use the information to provide feedback control. The present day approach has been to identify fundamental parameters of weld quality and devise methods to measure and control them.

This paper describes some of the work being carried out in devising practical systems for seam tracking and real time quality control.

**Seam Tracking Systems :**

The function of a seam tracking device is to provide automatic guidance for the welding torch along the joint. In order to do this, one has to obtain time-and position-based information which can be easily processed to enable exact positioning of the torch. The position signals are obtained with the help of suitable sensors or derived directly from the parameters of the welding arc.

The development of suitable sensors is the chief problem in the design of seam tracking systems. Special problems found in the vicinity of a fusion welding zone introduce further constraints in the selection of sensors. Some of the common distrubance sources found in the arc zone are shown in figure (1).

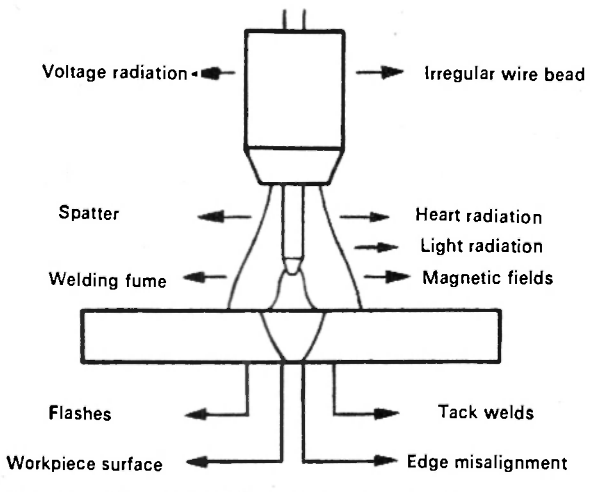


*Fig. 1. Sources of disturbance in tracking a joint.*

**Classification :**

It is possible to classify the tracking systems in a number of ways, depending on the mode of tracking (direct/indirect), sensor arrangement (ahead/lateral) or measurement principle (contact/contact less). As seen from figure (2), a wide choice is available and the selection of a particular method is based on availability of suitable measuring devices, joint geometry, etc. The high temperature and extensive radiation around the arc zone necessitate the use of indirect sensors and contactless measurement methods.

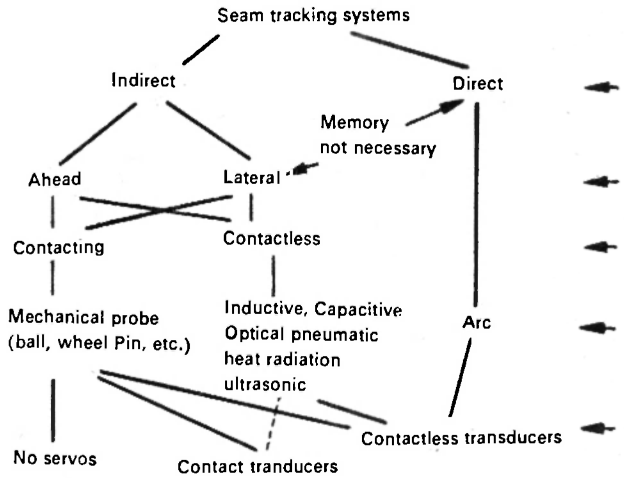


*Fig. 2. Classification of seam tracking Systems.*

The most common method in use is the photo sensitive cell positioned behind the weld to measure emitted radiation. The principle is clear from figure (3). Although successful in some instances, many difficulties are experienced in the use such sensors. They have been found to work best on aluminium alloys, where the thermal conductivity is high and the isothermals are widely spaced compared to steels. They are mostly employed for applications, such as the welding of tubes or drums in non-ferrous materials where backing bars would be difficult to insert and remove.

**Arc as a Sensing Device :**

To overcome the complications involved in the use of indirect sensors with contactless measuring methods, efforts have been directed to generate necessary information from the arc itself for controlling the position of the torch with respect to the joint i. e. to use the arc as a sensor.

Using the static and dynamic characteristics of the arc and its performance characteristic, it is possible to derive information regarding the position of the torch relative to the centre of the groove. Extensive study of the behaviour of consumable wire process like MIG/MAG and submerged arc welding, due to changes in torch to work piece distance, have shown that after the compensation by the self-regulating principle (burn off rate) the original operating point is not recovered. This

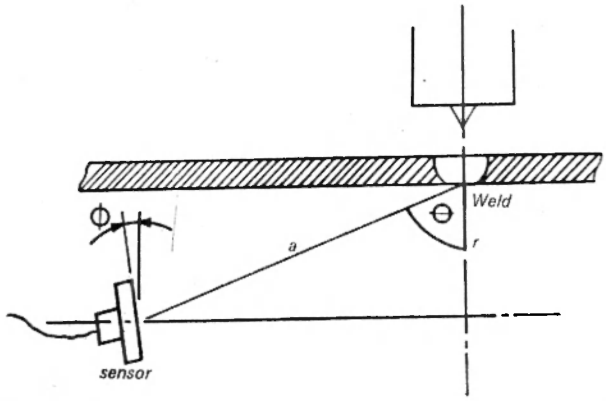


*Fig. 3. Photo sensitive cell positioned behind the weld.*

remnant change in operating point stems from the change in resistance of the section between contact tip and weld pool. The remnant arc length change is very small (< 10% of original) and not sudden. However, the remnant current duration is instantaneous and considerable (=2% of original). It is thus logical to use this, current deviation ($\triangle$I) as the controlled variable, inspite of the self-regulating process.

Measurement and feedback of remnant current deviation ($\triangle$I) has been employed to correct torch to work distance, centering of the torch etc. This has been best realised so far in a twin electrodes—consumable wire system. Since, when welding with two electrodes a quasi-stable condition is achieved through the two arcs burning on the groove faces, this data can be used for continually determining the torch position.

As shown in figure (4), the potential difference UI and U2 corresponding to the individual currents $I_1$ and $I_2$ are registered with suitable shunts and used for continuous torch guiding. By using $I_1 - I_2 = \triangle I$ and $I_1 + I_2 = I$, the transverse and vertical positions can be controlled.

The signals are amplified by difference amplifier and fed to solid-state regulators. Any deviations from the set values are registered and compared with the desired set values. This is used to control Right/Left or Up/Down motors. The tracking precision which also depends on the shielding gas or flux used and angle lies at ±0.4 mm.

Arc sensors in twin-electrode systems are also suitable for generating "arc-oscillations". This is particularly useful for vertical-up welding applications found in shipbuilding and tank construction.

**Automatic Quality Control Systems :**

Real time quality control i. e. monitoring of the quality of a weld as welding progresses, is an extremely

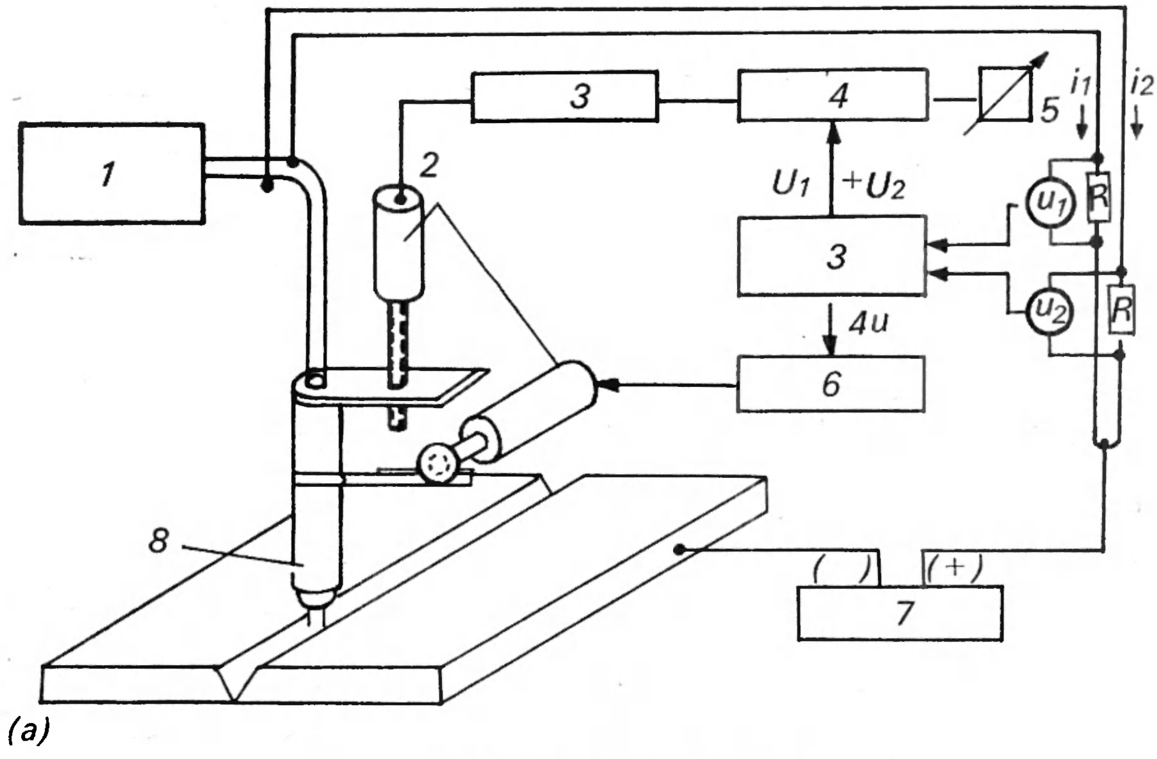


*Fig. 4. Twin Electrode adaptive Welding System.*

difficult task, particularly in fusion welding processes. The arc zone conditions, weld geometry and inaccessibility to back face of the weld put lot of restrictions on the choice of sensors. Furthermore very little is known about the parameters which really affect the quality of the weld. Hence, design of a system which would control all the quality parameters effectively is yet not possible. Systems have been developed to control only factors like penetration, weldpool size, solidification rate etc.

In general, feed back control systems using either optical or magnetic transducers or pulsing techniques have been employed for quality control with the availability of fully transistorized power sources, capable of accurately reproducing complex waveforms, it is now possible to control penetration, solidification rate etc. by proper wave shaping.

**Feedback Control Systems :**

Two types of systems are prevalent

(a) Measurement at the backface of the weld.

(b) Measurement at the frontface of the weld.

The former is resorted to when full penetration welds are required and there is access to the backface of the weld. When partial penetration is called for, front face measurements are used. Both methods have been found to give similar results.

The most commonly used system so far, has been the feed forward technique shown in figure (5). Here the conditions at a point ahead of the weld zone is first determined and the data used to correct welding parameters as needed. For example, the gap between the faces or fit-up differences is measured and compared with the desired set value and actions are taken to vary the parameters suitably. Similarly, it is possible to measure and alter the bead shape.

These systems however have limited application areas since they place a lot of restrictions on the total system.

**Pulsed Control Systems :**

The ripple-free output and high response of the transistorized power sources have been used for closed loop control of weld bead penetration successfully. Here, the arc voltage is monitored, the level of which is related to depth of penetration. On applying the pulse current the weld pool initially rises and then falls when penetration is achieved. As the arc voltage is directly related to the height of the weld pool, the degree of penetration can be monitored from changes in the arc voltage. The ability of a transistor power source to detect changes as small as 0.2V, enables very accurate penetration control.

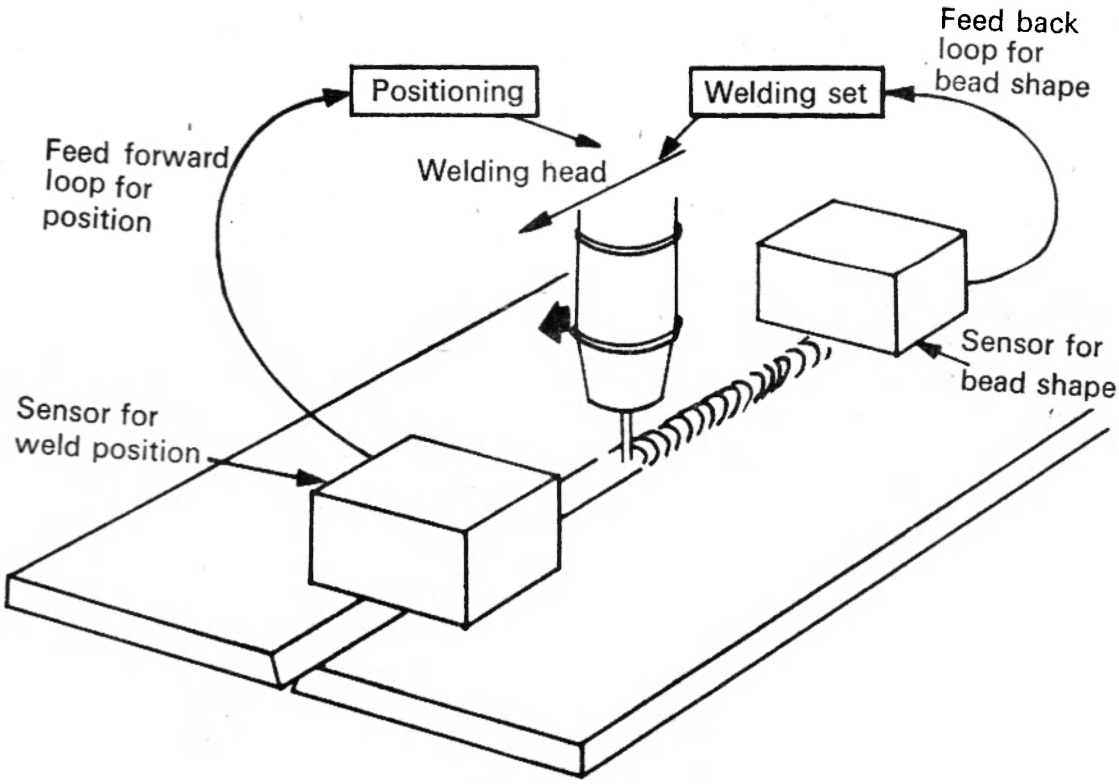


*Fig. 5. Feed forward System of Monitoring.*

The most important asset of a transistorized unit is its ability to accurately reproduce very complex waveforms as shown in figure (6). Solidification rate can be controlled by suitable wave sloping and this avoids such weld defects as porosity, undercutting, cracking and coarse grain structure.

With the advent of transistorized units, real time quality control is becoming easier and some of these have already been tranferred from the laboratory to the workshop.

**New Techniques of Weld Monitoring :**

As an extension of the high-speed Cine photography used for observation of arc phenomena, T. V. cameras have been developed for monitoring the welding arc. Coupled with suitable memory devices, these units allow direct observation of the arc and also enable corrections to be imposed automatically. Developments are still on in arriving at suitable neutral or differential filters which would filter unwanted radiations.

Compatibility of transistorised power sources for coupling with microprocessors or mini-computors have opened up new vistas for computer control of welding arcs. Mapping of the weld bead contour is an area where considerable progress has been reported.

Notable advances have also been reported in the following :

(a) television monitoring of arc length to control automatically the dilution in MIG surface cladding.
(b) television monitoring of joint profile dimensions and the position of the groove for submerged arc welding in shipbuilding.
(c) Monitoring of weld bead height, so that weaving width and gun position can be automatically selected in multipass MIG welding.
(d) Using the arc as sensor via a micro processor for joint tracking in MIG and TIG welding.

**Conclusions :**

Weld Monitoring techniques enable the operator to be relieved from the task of monitoring the weld cycle. Monitoring techniques for controlling the track or movement of the welding head and automatic quality systems have been developed with some success. Choice of sensors poses the greatest problem in designing monitoring systems. Usage of arc as the sensor has made possible direct sensing and is now employed for monitoring movement of the torch in two planes. Pulsed control

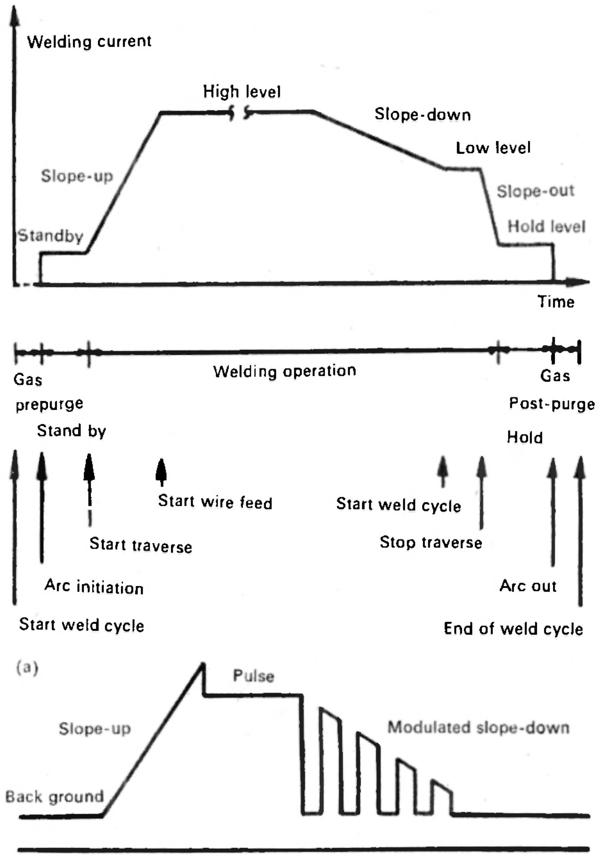


*Fig. 6. Complex waveforms for pulsed current operation.*

systems and feedback controls systems coupled with high response transistorised power sources have yielded some success in real time quality control. With new techniques like T. V. monitoring and computer control, Weld Monitoring will find extensive use in industrial applications. Practical systems are yet to be developed which control all aspects of weld quality at once. There is a strong commercial incentive for succeeding in this.

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