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INTELLIGENT CONTROL SYSTEM OF GAS TUNGESTAN ARC WELDING PROCESS IN AUTOMATIC ARC WELDING OF PRESSURE VESSELS

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1. Abstract

In automatic arc welding of pressure vessels and setting of welding conditions, surveillance and judgment of welding conditions, and sometimes adjusting operations of the electrode position was normally found to be very difficult especially when using manual Gas Tungsten Arc Welding process. In order to improve the above stated conditions it was necessary to develop an automatic judgment and adjustment of welding conditions, such as the electrode position, penetration etc. in this study, for the purpose of omitting surveillance of the welder in automatic TIG welding, an automatic intelligent surveillance that can control the whole system of GTAW process to maximum acceptable values was developed. A trial to confirm its suitability for the intended functions was done and proved to be effective.

2. Development of intelligent control system

For intelligent control of automatic welding it is necessary to automate surveillance and judgment of welding conditions system that changes by such disturbances occurs during degradation of the electrode shape and so on. Surveillance or judgment of welding conditions is to be carried out on the basis of fundamental welding conditions in consideration of welding position and other parameters. **Fig 1**: Shows the fundamental concept of the intelligent control system of Gas Tungsten Arc Welding process.

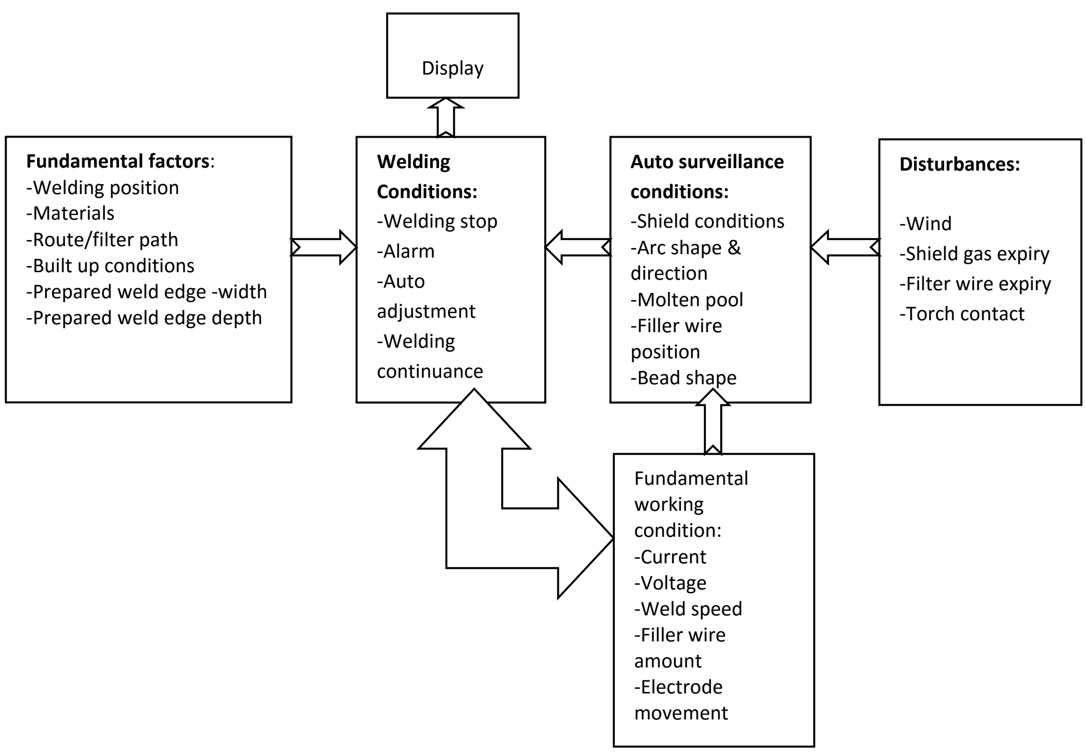
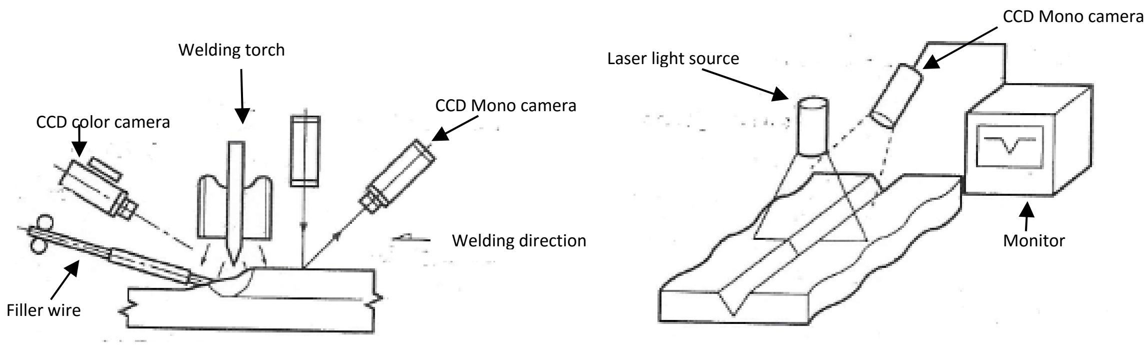


Figure 1. Fundamental concept of intelligent control system of TIG welding

Sensing of welding conditions is shown in Fig 2. ACCD color camera and microphone are arranged in front of the welding torch to watch the existing welding conditions. At the rear of the torch the bead shape and groove width are detected with laser beam irradiating system.



(a) Arrangement of detectors *(b) Detection process using laser slit beam*

2.1 Detection and Automatic judgment of welding conditions

Luminance of the arc is in the short – wavelength region of about 600mm or less. On the contrary, luminance of the molten pool is very high and is in in the long – wavelength region of about 600 nm or more. The CDD color camera has such a characteristics, that it decreases its sensitivity in the long wavelength of about 700nm or more, but picks up both the arc light and molten pool clearly by using proper interference and infrared filters together. Fig 3: Shows an example where an original image is processed through the above – mentioned procedures.

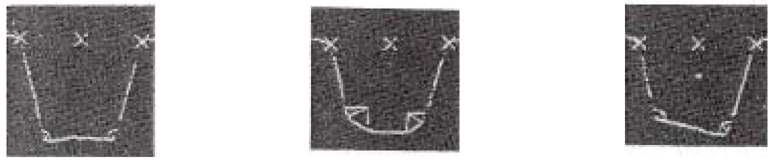
(a) Degrading of electrode *(b) Direction of arc* *(c) Position of filler wire*

Figure 3: Characteristic examples of welding conditions

2.1.1 Shape of Electrode

The electrode is normally worn during the welding process, and the arc is degraded in its concentration or deviated to cause lack of fusion. Therefore, surveillance of the electrode shape is very important. However, the electrode tip is obstructed and cannot be recognized and therefore it is picked up and recognized through the following procedure (see fig 3 (a)).

(1) Lower the welding current for a moment and pick up an image of the electrode tip. Process this image to obtain the outline of the electrode.
(2) Obtain the original outline of the electrode with the above obtained outline
(3) Obtain the worn-out mount and foreign matter at the tip in both outlines.



Base shape:	*Convex bead*	*Concave bead*	*Flat Bead*
Bead inclination:	*Normal*	*Normal*	*Declined to the right*
Bead shape:	*Bad*	*Good*	*Bad*

Figure 4: Detected examples of bead shapes

2.1.2 Direction of Arc

The arc may divide due to deviation of the magnetic field, deformation of electrode shape and other factors. The arc deviation is detected through the following procedures (see Fig 3. (b))

(1) Differentiate the image picked up with the welding current and that of the electrode tip shape of the above paragraph to obtain the arc shape.
(2) Obtain the centre position of the arc image and then obtain the centre position relative to the electrode tip.

2.1.3 Shape of Molten Pool

The molten pool which is the most important element in the welding is extremely difficult to recognize due to effects of the arc light. The recognition of the molten pool may only be done through the following procedures (see Fig. 3 (c))

(1) Taking notice of the fact that scattering of molten – pool luminance differs from that of the surrounding solid area in the original image, scan the whole area of the molten pool in front of the electrode tip, carry differential processing, and obtain the boundary.

(2) Convert the differential image in the polar coordinates (R – Ɵ coordinates) into the rectangular coordinates system (Ɵ; axis of ordinates and R; axis of abscissas).

(3) Apply such image processing method as the path evaluation tracing method to obtain the outline of the molten pool.
(4) Convert the outline reversely into the original polar coordinates system to obtain the regression express of the molten pool outline. The distance from the electrode tip "Y" becomes larger and therefore can be discriminated from the normal case.

2.1.4 Filler Wire

The filling position of the filler wire can be watched through the following procedures (see Fig 3(c).

(1) Divide the filler wire image beyond the supply nozzle in the original image into minute areas and convert them into the binary system
(2) Calculate the centre position of each area; extrapolate the centroid position distribution up to the electrode tip position to detect the deviation from the electrode tip.

2.1.5 Shape of Bead

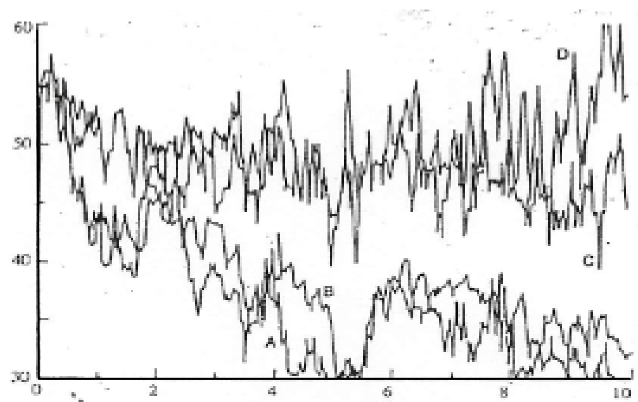
The shape of the bead is detected through the beam cutting method with a laser slip beam in the following procedures, as shown in fig. 2

(1) In order to avoid the effect of the highly- ruminant arc beam, set the power source of the laser beam on and off during low -welding current, and pick up the irradiated and non-irradiated images respectively to obtain two original images.
(2) Differentiate these two images to make the reflected light of the laser slip beam conspicuous.
(3) Obtain inscribed circle respectively near the groove face and groove centre section in the obtained image.
(4) Detect the kneading conditional of the bead from the radius of curvature of the circle obtained near the groove face, and the roughness and inclination of the beam from the radius of curvature of the circle obtained near the groove centre section.

2.2 Detection of welding abnormalities with welding sounds

Welding sounds contain information on welding conditions. As shown in fig 5 (a) the level of the background noises, such as jet noises of the shield gas, noises generated from the welding power sources, etc decrease as the frequency increases. However, when the arc is disturbed by leaking of welding sounds of high levels are recognized in frequencies from the low region to high one. The figure 5: (b) shows secular change examples of welding sounds obtained at a low background noise level through about 9 - 11 KHz band – good pass filter. With this diagram, by monitoring welding sounds, welding abnormalities can be detected when the shield is distributes with cross- wind.

Sound pressure (dB)



Frequency (kHz)

Figure 5: Welding abnormalities detection using welding sound

2.3 Electrode Position control by fuzzy inference

Since many factors have effects on the shape of the bead, the electrode position control by fuzzy inference is simple on the basic information of the shape of the bead.

Inputs for the fuzzy inference were the bead inclination, electrode position deviation from the groove width, the electrode moving direction and speed when it moves. Outputs were the groove width, the electrode moving direction and speed. The bead inclination was obtained on the shape of the bead. The electrode deviation from the groove width was obtained with the edge width and electrode position obtained from the reflected light of the laser slip beam. The membership function of each input was a triangular type fuzzy variable. Algorithm was composed of 22 rules, and outputs were obtained in seven intensity levels through the "Algebraic product – addition – centroid method".

2.4 Manufacturing of a trial intelligent control system of TIG welding

On the basis of the above- mentioned study results, the intelligent control system for narrow – gap TIG welding was manufactured. The functions described in the above section worked effectively and a sound welding was obtained.

3. Conclusion and Recommendations

The fundamental technology that automates an intelligent control surveillance and judgment of welding conditions and adjusting operations of welding conditions are among the roles of the welder in automatic TIG welding. The welding conditions could be recognized by means of the visual and sound information of the welding area. On the basis of the results obtained, an intelligent control welding system was manufactured and carried out a number of welding tests to confirm its functionalities. The system confirmed to work effectively and a sound welding bead was obtained.

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