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Feasibility Study for In-Process Monitoring of Gas Tungsten Arc Welding

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Abstract:- Different methods can be adopted for monitoring the quality and prediction of process stability for Gas Tungsten Arc Welding. **T**he acoustic emissions generated during welding of V groove weld for SS304 material can be utilized to assess the behaviour of weld produced and analyze using softwares. For evaluation of influences of sound generation, extensive experiments have to be performed and a comparative study can be carried out.

Keywords:- In-process monitoring, acoustic emission, process parameters, response variables, GTAW.

I. INTRODUCTION

In today's manufacturing field, Quality and Productivity play a vital role. All the industries focus on producing better quality product at minimum cost and increase productivity in this very stiff and cut throat competitive market condition. Welding, being the most basic and crucial manufacturing process is adopted by many companies for the fabrication work. Of all joining processes, welding gives the strongest joint.

The traditional monitoring includes controlling the process parameters like welding current, arc voltage, gas flow rate, welding speed, etc. and non-traditional monitoring includes radiographic inspection, ultrasonic testing, sound wave emissions, arc radiation rate, etc. Monitoring by traditional processes is a kind of post process inspection. Hence, obtaining a sound weld in an ongoing process becomes difficult. This considerably increases inspection time and if weld is found defective, chances of rejection arise. These difficulties can be overcome by in-process monitoring i.e. monitoring is done while the process is going on by non-traditional monitoring processes.

II. GAS TUNGSTEN ARC WELDING (GTAW)

GTAW process is the most common operation used for joining two similar or dissimilar metallic pieces with or without heating the material or by applying the pressure or using the filler wire for increasing productivity with less time and cost constraint. A shielding gas is used like Argon, Helium, Nitrogen, etc. to avoid atmospheric contamination of the molten weld pool (as shown in fig. 2). Filler wire may be added depending upon the type of weld required and weld geometry. The arc is struck either by touching the electrode with a tungsten piece or using a high frequency current. In the first method, arc is initially struck on a scrap tungsten piece and then broken by increasing the arc length. This procedure is repeated twice or thrice which warms up the tungsten electrode. The arc is then struck between the pre-cleaned work-piece. This method avoids breakage of electrode tip, work-piece contamination and loss of tungsten from electrode. In the second method, a high frequency current is superimposed on the welding current. The welding torch is brought closer to the job. When electrode tip reaches at 2 to 3 mm distance, a spark jumps across the air gap between the electrode and the work-piece. Hence, arc is established. During welding, shielding gas is allowed to impinge on the solidifying weld pool for a few seconds even after the arc is extinguished. This avoids atmospheric contamination of the weld. The welding torch inclined at angles of 70-80˚ with the flat work-piece and commonly a leftward technique is used.

Change in various welding parameters such as welding current, gas flow rate, electrode angle, etc. influences responsive output parameters such as weld penetration, depth to width ratio, strength of weld joint, etc. and better quality can be achieved by adopting optimization. Also, GTAW provides a better control on welding as clear visibility of arc and work-piece, smoother and sound weld is obtained in all welding positions with least spatters. Hence, it is suitable for high quality welding of thin material.

III. LITERATURE REVIEW

Jožef Horvat et al. [2] stated that in an industrial environment, background noises are caused by secondary sources and reverberation (parasitic) noises are caused by reflection. The sound impulse as well as the turbulent noises are additionally influenced and contaminated, and even overlapped by background noise. To check the effect of background noise, the sound pressure levels with and without a welding process have to be measured. If the difference between them is found greater than 10 dB, then the effect of the background noise is negligible. On contrary to this, if background noise is equal or higher than the common level of noise, then the noise due to welding process is negligible and welding noise measurement proves invalid. In some cases, the background noise can be extracted by filters. Hence, experimentation can be done in silent environment to reduce the effect of external sounds.

R.Sathish et al. [3] explained that Gas Tungsten Arc Welding produces an arc between a tungsten electrode and the work-piece. An inert gas shields the arc, electrode and molten pool from atmospheric contamination. While welding thinner materials, edge joints and flanges, welders generally do not use filler metals. However, for thicker materials filler metal is used. It is a popular technique for joining thin materials in the manufacturing industries. This type of welding achieves a high quality weld for stainless steels and non-ferrous alloys. Compared with Gas Metal Arc Welding, the major limitations of GTAW include its inferior joint penetration and its inability to weld thick materials in a single pass. The threshold for butt-joint penetration when welding stainless steel plates using a single pass GTAW process is only 3 mm. Hence, monitoring for multiple passes has to be considered.

J. Hoffman et al. [4] mentioned that an acoustic signal recorded by means of a microphone, is proportional to the acoustic pressure P_A, which represents a change in pressure in the medium with respect to the equilibrium pressure. This is a variable signal with mean value zero.

Eber Huanca Cayo et al. [5] have tested arc voltage and sound pressure signals for Gas Metal Arc Welding. It has been summarised that its monitoring by digital analysis of acoustical welding parameters enables one to detect disturbances related phenomena that occurs in welding arc and can influence the process stability.

S. P.Gadewar et al. [6] investigated the effect of process parameters of GTAW like weld current, gas flow rate, work piece thickness on the bead geometry of SS304. It was found that the considered process parameters affected the mechanical properties upto a great extent.

IV. IN-PROCESS MONITORING

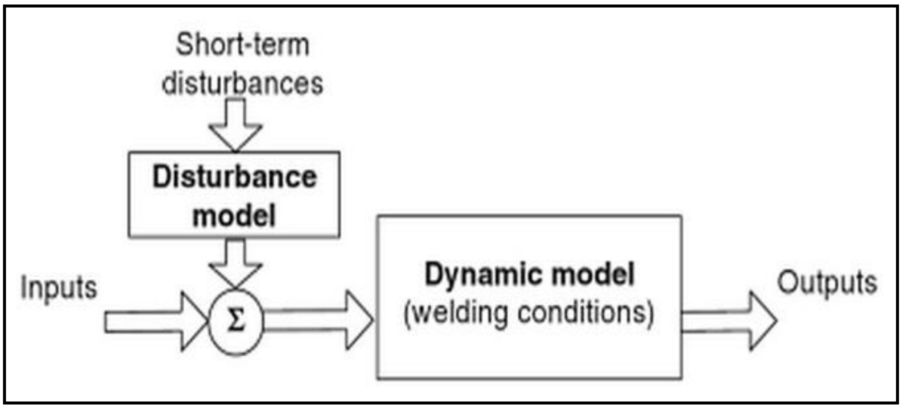

Fig.1: Inclusion of disturbances during welding [6]

Acoustic emission analysis, being an extremely effective technology can be used for a wide range of usable applications of Non Destructive Testing. Solid materials have certain elasticity. They become compressed or strained under the effect of external forces and also show spring back phenomenon. The higher the force, the higher will be elastic deformation i.e. higher elastic energy. A fracture generates if the elastic limit is exceeded either immediately or after certain plastic deformation. If the elastically strained material contains a defect like non-metallic inclusion, weld joint defect cracks, etc. during welding process, they rapidly release the elastic energy which creates an acoustic emission event. Appropriate sensors can be used to detect the propagation of elastic wave. The frequency of Acoustic emission testing of metallic objects is an ultra-sound, generally ranging between 100 and 300 KHz. Movement of dislocations generated due to plastic deformations can be measured reliably at a short sensor distance and proper laboratory environment. Most of these processes produce continuous signals. For Gas Tungsten Arc Welding, possible sources of acoustic variation are changes in dimension, geometry and gas flow, metallic transfer, molten pool movement, etc.

The steps involved in this process are as follows:
1) Collection of acoustic emission signals, operating current, inert gas flow rate and available voltage.
2) Extraction of features from the recorded signals.
3) Estimation of process using pattern recognition, regression analysis, etc.

V. EXPERIMENTATION

A. Material Selection

The selected base metal is stainless steel (SS304) having plate thickness 10mm with chemical composition as shown in Table 1 and chemical composition of selected filler wire (Ø2mm) is shown in Table 2.

Table I: Chemical Composition of Work-piece

Jindal Designation/code	%C	%Mn	%P	%S	%V	%Cr	%Ni	%Mo	%Fe	N PPM
J-304 L	0.030	1.19	0.045	0.030	0.28	17.93	8.56	0.27	Rest	1000

Table II: Chemical Composition of Filler Rod

Electrode code	%C	%Mn	%Si	%Cr	%Ni	%Mo	%Fe
ER-316L	0.02	1.50	0.40	19.00	12.00	2.0	Rest

B. Experimental Set-up

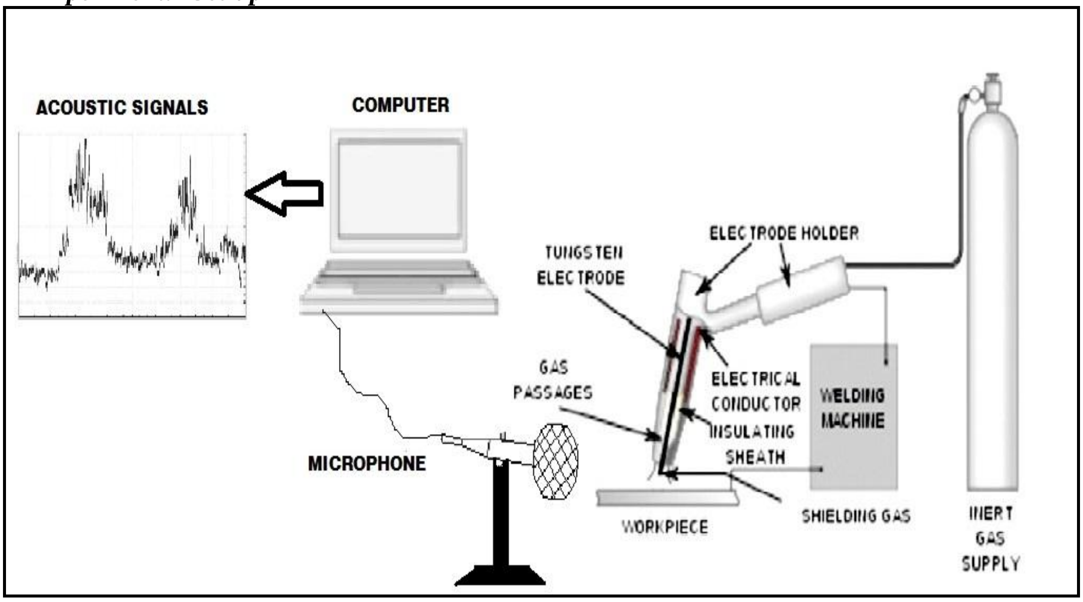

Fig.2: Experimentation set-up

The fig.2 shows the schematic arrangement of set up for experimentation. A unidirectional microphone of frequency response up to 12,000 Hz is used. It is arranged at optimum distance from the work-pieces which has been decided on the basis of preliminary experiments. The process parameters considered during the experimentation are shown in table 3. The sensed acoustic signals are detected using software and relationships between various descriptors can be studied. Prediction of irregularities can be done by comparing these recorded signals.

Table III: Range of Process Parameters

Process Parameter	Range
Operating Current	100-180 A
Inert Gas Flow	7-15 l/min

VI. PRELIMINARY RESULTS

In the preliminary experiments, Gas tungsten Arc Welding was carried out for two work-pieces keeping gas flow 10 l/min and current 140A and 160A for work-piece 1 and 2 respectively. These results were analyzed for checking whether they reveal correct results or not. Hence, the following two figures depict a comparison between sound waves variation with weld quality produced.

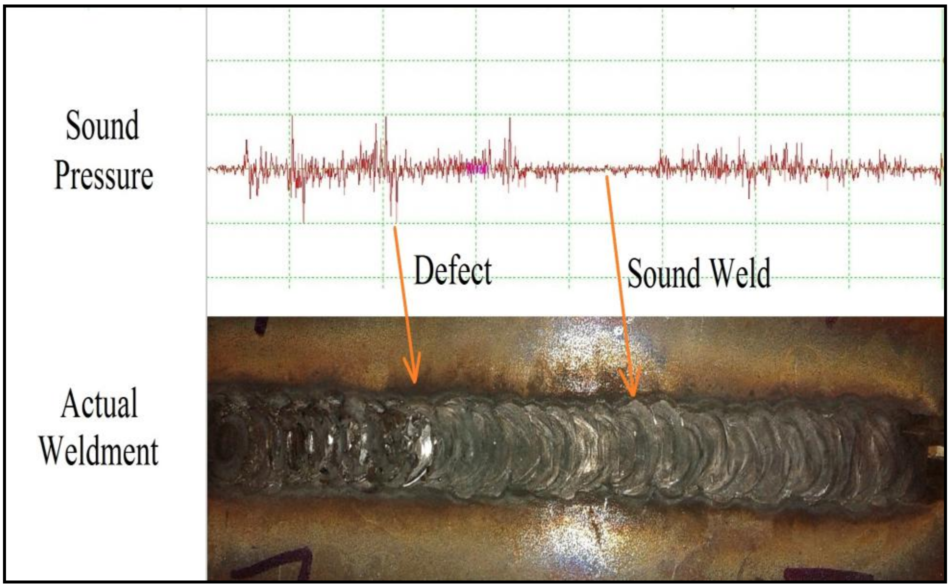

Fig.3: Comparison of acoustic waves with weld quality for work-piece 1

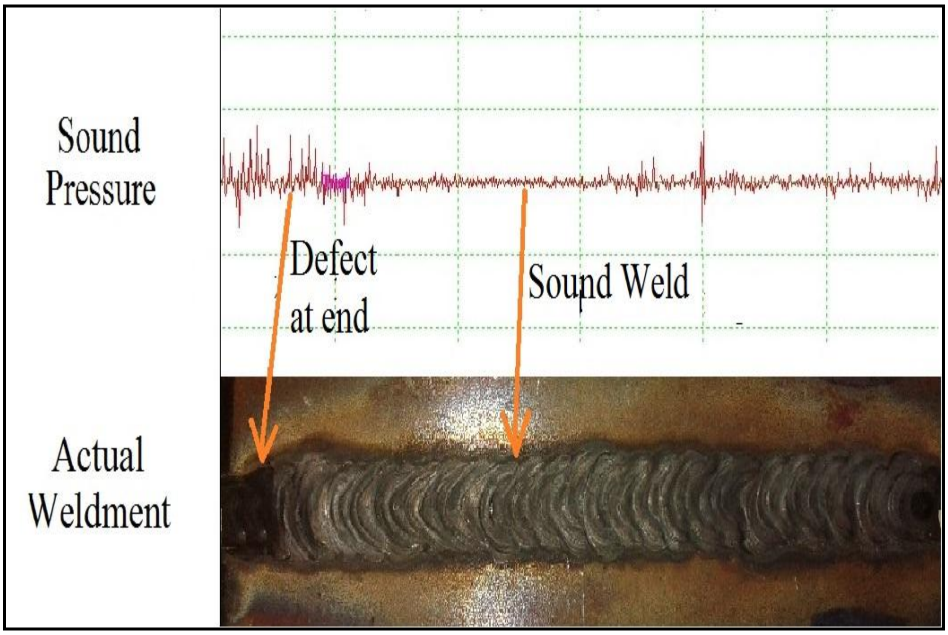

Fig.4: Comparison of acoustic waves with weld quality for work-piece 2

From fig. 3 and 4, it can be concluded that the technique for monitoring of Gas Tungsten Arc Welding using acoustic emissions fits well for in-process monitoring.

VII. CONCLUSION AND FUTURE SCOPE

Use of Acoustic Emission signals as one of the important means for in-process monitoring of welding can also be applied for controlling other manufacturing processes. Detection of defects during the process itself provides a better control over the process and thereby quality can be controlled without generation of major losses observed during the end of the process.

For knowing the effect of control variables on responding parameters precisely, a number of experiments should be carried out. For this purpose, Design of Experiments (DOE) technique can be used so that experiments can be performed systematically. Two control variables namely Operating current and Inert gas flow can be varied for three different levels for conducting a number of experiments. To find out the significance of the effect of control variables on response parameters, Analysis of Variance (ANOVA) can also be performed. Furthermore, Regression model development showing relationship between the control variables and response variables can be developed.

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