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Study & Analysis of Process control & Automation Development in welding Process

Pramjeet Kumar[1], Jag Mohan[2]

[1,2]M.Tech. Scholar, Dept. of Mech. Engg., UIET MDU Rohtak, Haryana, India

ABSTRACT

This paper reviews the process control techniques which have been applied to enhance the productivity and quality of welded joints. It seeks to explain the influence of power source design and computer control on these developments. In particular it will address the real time control of short arc GMAW and explain how by modulation of the transient electrical properties and high speed wire feed oscillation process performance has enhanced in several recent variants of controlled short circuit transfer. An attempt is also made to put these developments in context when compared to conventional GMAW, and to explain the potential benefits and to classify them according to recent IIW metal transfer scheme. The process control potential of other developments; such as tandem and hybrid laser GMAW with also be described. The trends in welding automation are reviewed and in particular the techniques for off line and rapid programming of welding robots and on line monitoring and control techniques will be reviewed. Finally the continued importance of fundamental studies into process control and automation is stressed.

INTRODUCATION

Why do we need to develop improved welding process control and automation techniques? The answer lies in current international concerns about the restricted availability of skilled welders, the increasing need to improve occupational health and safety both in the workshop and general environment, pressure to improve productivity and reduce cost and the need to maintain joint integrity in critical structures.

The shortage of skilled welders has been highlighted in the media; for example: The Wall Street journal reviewed the problem in 2006 [1] indicating a major shortage of welders and escalating weekly earnings. The same article claimed that on current estimates demand for skilled welders in the US will outstrip supply by 200000 by 2010. This is by no means an isolated problem; it has been reported as an international problem in countries such as Japan, and Australia as well as in Western Europe. There is believed to be a link between the perceived OH&S hazards associated with welding and the ability to recruit new welding personnel.

OH&S is an issue which must be addressed due to our moral responsibility to welders and society in general as well as the recent and sometimes ill conceived spate of litigation which often exploits our lack of technical knowledge concerning the physical effects of welding hazards.

In terms of cost and productivity it is known that in most common welding operations (on plain carbon steel) labour accounts for 70 to 80% of the total welding cost. Since labour costs are escalating, and will inevitably do so even in developing economies, total fabrication costs will increase accordingly. Productivity improvements are difficult to envisage in such a labour intensive, highly skilled and OH &S affected environment.

Principle of GMAW

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a welding process in which an electric arc forms between a consumable wire electrode and the workpiece metal(s), which heats the workpiece metal(s), causing them to melt and join [12].

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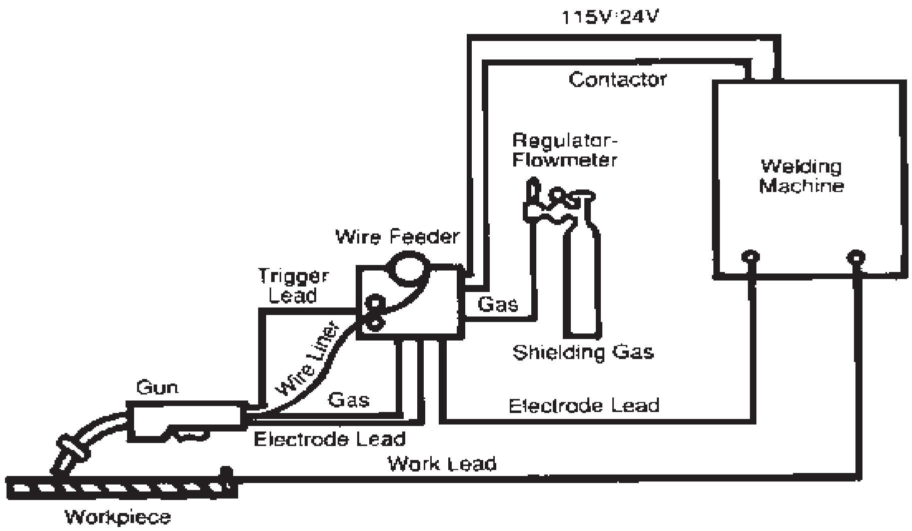
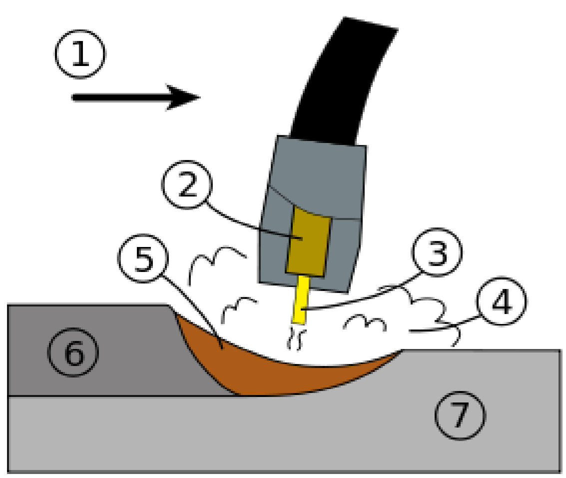


Figure 1: Schematic setup diagram of Gas Metal Arc Welding.

This is shown in fig. 1.describes the schematic setup of Gas Metal Arc Welding for how the welding will do the work. The tool is attached to negative terminal and the work piece is attached to anode terminal. After the potential differences apply by power supply crossways the small gap develops adequately high electrical discharges through the small break in the form of the spark in interval of 10 of mi seconds. Then the electron ions are present accelerated towards the positive ions, bringing on a discharge passage that turn out to be conductive. It is only at a given instant of time when the suitable voltage is built up across the tool and work piece the accelerated electron ions may ultimately collisions with the Electrode fluid molecules causing creation of a passage of plasma. An instant fall of the electrical resistance of the plasma passage permits that current density attains very large amounts, creating a rise of ionization between molecules and powerful magnetic field results of a very high temperature on the electrodes in the range of (10000 - 12000ºC). This high temperature spark causes sufficiently compressive force developed between work piece and tool as an outcome that more or less metallic particles are liquefied and eroded [2].

LITRATURE REVIEW

PCGMAW process is a promising hybrid process and an active area of research specially for normalizing the GMAW's necessary process conditions and performance characteristics. Basic GMAW process comprises four main elements Tool electrode, Work piece, with a Control system as show in Figure 2.



GMAW weld area. (1) Direction of travel, (2) Contact tube, (3) Electrode, (4) Shielding gas, (5) Molten weld metal, (6) Solidified weld metal, (7) Workpiece.

Fig 2: Basic GMAW System elements.

The stationary welding gap is replaced by dynamic reciprocating motion of sub-system (Tool, Workpiece and Electrode) with intention to enhance flushing of Electrode fluid and necessary discharge conditions. Several researchers have reported a comparable improvement in performance of PCGMAW process through this. On the basis of retrospective review PCGMAW process can be classified broadly according to mode of vibration transverse. A brief discussion has been given in this next section[3].

Work piece Vibration in PCPSU

The same pumping and hammering effect can be obtained if the ultrasonic vibration introduced to the work piece. The inertial force set up in work piece due to vibration will also help in expelling debris and molten metal from the machined surface and welding corridor. The efficiency of the ultrasonically aided micro-PSU is eight times than that of micro-PSU under predetermined welding conditions with a fact of improved Electrode circulation. Work piece UV increases the flushing effect, when high amplitude combined with high frequency increases the WB. There is a little effect of ultrasonic vibration on drilled hole's dimension. Ultrasonic vibration at 60% of the peak power with capacitance of 3300 PF gives best WB with minimum tool wear rate. UV cause pressure variation all along the gap, results in better flushing effect increases process stability and decrease tool wear, this reciprocating action generate suction force in welding zone so more molten metal is exposed to fresh Electrode fluid and accelerate melting evaporation and re-solidification. Flushing effect internally caused by ultrasonic vibration and externally by the planetary motion of the tool electrode result in lower electrode wear results minimum dimensional inaccuracy. UV reduces the average length, width and number of micro-cracks with the discontinuous ultrasonic vibrations; it leaves less volume of re-solidified material in each crater which gets quenched with surrounding Electrode leaving a rougher surface with small micro cracks[4].

METHODOLOGY

The graph theoretic is a decision making tool through logical and systematic approach. The ultimate goal of GTA is to modeling and analyzing objective function through mathematically entities to evaluate complicated direction relative importance and interactions exist among qualitative/quantitative factors of a system. Rao and Gandhi (2002) proposed digraph and matrix method to evaluate machinability of wokpiece and failure cause analysis of machine tool. Gandhi and Agarwal (1994) presented GTA methodology for system wear analysis. Jangra et al (2010) applied this methodology to evaluate the performance of carbide compacting die manufactured by wire PSU. Several others have proposed graph theory approach in the fields of science and technology. It is new in manufacturing technology[5].

Table 1: The PCPSU performance factors and their references frequency /source

Factors	Mode of Vibration	Affects
Flushing (H_1)	Tool	Debris and gas bubble accumulation, Fresh Electrode transfer.
	Workpiece	
	Electrode	
Cavitation (H_2)	Tool	Acoustic stream, Ultrasonic field force, Bubble nucleation, expansion and violent collapse.
	Workpiece	
	Electrode	
Abnormal Discharge (H_3)	Tool	Arcing, Short circuits and Discharge wave distribution
	Workpiece	
	Electrode	
Dimensional Accuracy (H_4)	Tool	Aspect ratio Tool Wear
	Workpiece	

	Electrode	Over Cut, Taper Cut and Circularity
Surface Defects(H_5)	Tool	Thickness of recast layer, Micro holes & cracks, Residual stress, Micro-Hardness and Heat affected Zone
	Workpiece	
	Electrode	
Ergonomics and chemical Effects(H_6)	Tool	Pollution due to unwanted gases and Chemical reactions in PSU
	Workpiece	
	Electrode	

The PCPSU performance factors are identified and grouped in this paper, high noted with probability rather than certainty previously. The GTA approach provides a systematic characteristic of the PCPSU performance, although new for advance manufacturing technology, to avoid guessing and intuition in arriving at conclusions. The six broad factors are used to evaluate the extent of the PCPSU process performance index [11]. Thus;

PCPSU Performance index = f (H1,H2,H3,H4,H5&H6)

Where H1,H2,H3,H4,H5&H6 represent the factors affecting the PCPSU performance. The graph theoretical methodology comprises the digraph representation, the matrix representation and the permanent function representation. The digraph is the visual representation of the characteristics and their relative importance. The matrix converts the digraph into mathematical form. The permanent function is a mathematical model that helps to determine index [6].

RESULTS & DISCUSSIONS

Digraph representation for PCPSU process performance:
A digraph is used to represent the conditional factors of PCPSU process and their relative importance in terms of nodes and edges. A PCPSU process performance digraph represents the process stability measure of characteristics or factors (Hi's) through its nodes and the edges correspond to the importance of factors (hij's). 'hij' indicates relative importance of the jth factor over the ith factor. In the digraph hij is represented as a directed edge from node i to node j. The digraph permits us to visualize the PCPSU performance factors and gives a feeling of relative importance between the factors. These six factors are schematically represented the corresponding PCPSU performance digraph is presented in Figure 3. PCPSU performance factors digraph models the welding factors and their relative importance [7].

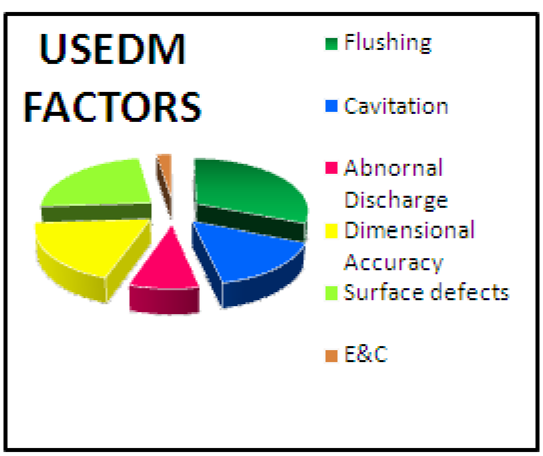


Fig. 3: Contribution of various factors effecting in PCPSU performance

Researchers have less explored the influence of factors such as abnormal discharge (23.7%) and ergonomics and chemical reactions (6.8%), where as flushing of contaminated Electrode fluid (84.7%), dimensional accuracy (50.8%) and surface Morphology (64.4%) are the most significant contributing factors found affecting the performance of PCPSU process , the effect of cavitation (42.4%) also considered [10].

PCPSU process performance Matrix representation

Since a digraph is a visual representation, it helps in analysis to a limited extent only. To establish an expression for performance index, the digraph is represented in matrix form, which is convenient in computer processing also. A digraph of M factors leading to a M^{th} order matrix A = [h_{ij}]. This is an $M\times M$ matrix and considers all factors (i.e., H_i) and their relative importance (i.e., h_{ij}). This matrix [A], for the PCPSU performance index digraph in equation (1) for the ultrasonic vibration assisted Ultasonic process as;

$$\begin{array}{cc} Factors & \begin{array}{ccccccc} H_1 & H_2 & H_3 & H_4 & H_5 \ldots & H_m \end{array} \\ [A] = \begin{array}{c} H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \\ \vdots \\ H_m \end{array} & \begin{bmatrix} H_1 & h_{12} & h_{13} & h_{14} & h_{15} \ldots & h_{1m} \\ h_{21} & H_2 & h_{23} & h_{24} & h_{25} \ldots & h_{2m} \\ h_{31} & h_{32} & H_3 & h_{34} & h_{35} \ldots & h_{3m} \\ h_{41} & h_{42} & h_{43} & H_4 & h_{45} \ldots & h_{4m} \\ h_{51} & h_{52} & h_{53} & h_{54} & H_5 \ldots & h_{5m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ h_{m1} & h_{m2} & h_{m3} & h_{m4} & h_{m5} \cdots & H_m \end{bmatrix} \end{array} \quad (1)$$

The rows and columns in the matrix represent relative importance among factors, i.e. hij represents the relative importance of the ith factor with the jth factor: where Hi is the value of the ith attribute represented by node,hij is the relative importance of the ith attribute over the jth represented by the edge hij. The permanent of this matrix A, i.e., per [A], is defined as the PCPSU performance index functions with six factors along relative importance are expressed in equation (2).

$$\begin{array}{cc} Factors & \begin{array}{cccccc} H_1 & H_2 & H_3 & H_4 & H_5 & H_6 \end{array} \\ [A] = \begin{array}{c} H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \\ H_6 \end{array} & \begin{bmatrix} H_1 & h_{12} & h_{13} & h_{14} & h_{15} & h_{16} \\ h_{21} & H_2 & h_{23} & h_{24} & h_{25} & h_{26} \\ h_{31} & h_{32} & H_3 & h_{34} & h_{35} & h_{36} \\ h_{41} & h_{42} & h_{43} & H_4 & h_{45} & h_{46} \\ h_{51} & h_{52} & h_{53} & h_{54} & H_5 & h_{56} \\ h_{61} & h_{62} & h_{63} & h_{64} & h_{65} & H_6 \end{bmatrix} \end{array} \quad (2)$$

The permanent is a standard matrix function and is used in combinatorial mathematics **Error! Reference source not found.**. Use of this concept in PCPSU performance index evaluation will help in representing performance index of mode of vibrations as obtained from combinatorial consideration. Application of this permanent concept will lead to a better appreciation of performance index factors of the PCPSU mode of vibrations. By using this, no negative sign will appear in the expression (unlike the determinant of a matrix in which a negative sign can appear) and hence no information will be lost [8].

The minimum performance index value for the PCPSU process giving all factors extreme unimportance that is; per [Amin] = 0.188535 X107.

The value of permanent function of each mode of vibration is evaluated by generalized equation.. The performance function matrixes have been provided in equation (3, 4 and 5) using generalized performance matrix function equation . These values of Hi are selected from Table 4.

$$\begin{array}{cc} Factors & \begin{array}{cccccc} H_1 & H_2 & H_3 & H_4 & H_5 & H_6 \end{array} \\ [A^{Tool}] = \begin{array}{c} H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \\ H_6 \end{array} & \begin{bmatrix} 9 & 8 & 8 & 6 & 6 & 9 \\ 2 & 4 & 5 & 2 & 3 & 7 \\ 2 & 5 & 4 & 3 & 3 & 6 \\ 4 & 8 & 7 & 6 & 6 & 9 \\ 4 & 7 & 7 & 4 & 6 & 9 \\ 1 & 3 & 3 & 1 & 1 & 2 \end{bmatrix} \end{array} \quad (3)$$

$$\begin{array}{ccccccccc} \text{Factors} & & H_1 & H_2 & H_3 & H_4 & H_5 & H_6 & \\ & \begin{array}{c} H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \\ H_6 \end{array} & \multicolumn{6}{c}{\begin{bmatrix} 9 & 8 & 8 & 6 & 6 & 9 \\ 2 & 1 & 5 & 2 & 3 & 7 \\ 2 & 5 & 4 & 3 & 3 & 6 \\ 4 & 8 & 7 & 7 & 6 & 9 \\ 4 & 7 & 7 & 4 & 3 & 9 \\ 1 & 3 & 3 & 1 & 1 & 1 \end{bmatrix}} & \end{array}$$

$$[A^{workpiece}] = \begin{array}{c} H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \\ H_6 \end{array}\begin{bmatrix} 9 & 8 & 8 & 6 & 6 & 9 \\ 2 & 1 & 5 & 2 & 3 & 7 \\ 2 & 5 & 4 & 3 & 3 & 6 \\ 4 & 8 & 7 & 7 & 6 & 9 \\ 4 & 7 & 7 & 4 & 3 & 9 \\ 1 & 3 & 3 & 1 & 1 & 1 \end{bmatrix} \quad (4)$$

$$[A^{Diele\ ctric}] = \begin{array}{c} \\ H_1 \\ H_2 \\ H_3 \\ H_4 \\ H_5 \\ H_6 \end{array}\begin{array}{c} \begin{array}{cccccc} H_1 & H_2 & H_3 & H_4 & H_5 & H_6 \end{array} \\ \begin{bmatrix} 9 & 8 & 8 & 6 & 6 & 9 \\ 2 & 6 & 5 & 2 & 3 & 7 \\ 2 & 5 & 1 & 3 & 3 & 6 \\ 4 & 8 & 7 & 8 & 6 & 9 \\ 4 & 7 & 7 & 4 & 6 & 9 \\ 1 & 3 & 3 & 1 & 1 & 1 \end{bmatrix} \end{array} \quad (5)$$

A computer program in MATLAB has been developed for to solve the permanent functions. The PCPSU performance index values for three mode of vibration can be raked as in table 2. Electrode medium ultrasonic vibration as the first rank, Tool UV as second and workpiece Vibration as third [9].

Table 2: PCPSU performance Index values for three Modes of Vibrations

PCPSU mode of vibration	Permanent of performance Index [A]	Maximum performance Index	Minimum performance Index
Electrode	4.64165 X 106		
Tool	4.51851 X 106	16.4901 X 106	1.88535 X 106
Workpiece	3.75519 X 106		

CONCLUSIONS

The unique contribution of the present work is to quantify the effects of various factors in the implementation ultrasonic vibration in traditional PSU process. The relative importance of the factors denotes the importance of that factor regarding other factor under consideration, but they also discourage from adapting mode of vibration in PSUs. Hence, it becomes very much to evaluate the relative importance for their better control. It has been observed in the considered example that besides flushing and Dimensional accuracy, cavitation also has a significant intensity. As a cavitation factor is being considered significantly in Electrode medium vibration and increase the PCPSU performance significantly, one cannot ignore the cavitation aspect of ultrasonic vibration implementation and its repercussions.

The mathematical model proposed in this paper can develop a suitable hypothesis for implementing ultrasonic vibration in tradition Ultrasonic process based on the relative importance of different proposed factors. This would help control of process conclude the improvements needed in traditional PSU systems. However, this approach is somewhat a new thinking in the domain of PCPSU. As no new work is perfect, the present work is also associated with some limitations:

This approach can further be utilize to evaluate the performance of various hybrid process used in Advance manufacturing technology to analyze the effects of various hypothesis pre-assumed.

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