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USING ANALYTICAL HIERARCHY PROCESS FOR OPTIMIZATION OF GAS METAL ARC WELDING (GMAW) PARAMETERS

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Abstract- *Among the arc welding processes, gas metal arc welding (GMAW) is a popular process to the present day fabrication industries. A detailed study on welding as well as on MIG welding has been carried out. Controlling process parameters of gas metal arc welding is very important to obtain the desired product quality. A very few important parameters are discussed in this report. This report presents a literature review of the applications of Analytic Hierarchy Process (AHP). AHP is a multiple criteria decision-making tool that has been used in almost all the applications related with decision-making. Out of many different applications of AHP, this work covers a few, which could be of wide interest to the researchers and practitioners. In the present work, parametric optimization has been done in gas metal arc welding applying the analytical hierarchy process (AHP). This technique shows quite close estimates with the experimental results.*

Keywords: GMAW, MIG welding, AHP, Filler metal.

1. INTRODUCTION

Gas metal arc welding (GMAW), formerly known as metal inert gas (MIG) welding, utilizes an arc maintained between the work pieces and an automatically servo feed wire electrode [1]. The arc continuously melts the wire as it is fed to the weld puddle. In this process, the consumable electrode provides the filler metal, which is feed through the electrode holder into the arc. So no additional fed is required. The weld metal is shielded from the atmosphere by a flow of an inert gas, or gas mixture [2]. Argon, helium, and mixtures of these two gases can be used for welding steel, some O_2, CO_2 is usually added to improve the arc stability and reduce the spatter [3]. The cheaper CO_2 can be used alone when welding steel provided that a deoxidizing electrode wire is employed. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used [4].

The Analytical Hierarchy Process (AHP) is a comprehensive, logical and structured framework which developed in the 1970s by mathematician Thomas L. Saaty, now a professor at the University of Pittsburgh's Katz School which allows of improving, understanding of complex decision by decomposing the problem [5].
The decisions that are described by these criteria do not fit in a linear framework they contain both physical and psychological elements AHP allows better, easier and more efficient identification of selection criteria, their weighting and analysis [6]. It reduces drastically the decision cycle.
The analytical hierarchy process (AHP) is a general problem solving method that is useful in making complex decisions based on variables that do not have exact numerical consequences [7]. Decision making by using analytical hierarchy process (AHP) typically consists of following five steps [8].

1. Structuring the decision model
2. Entering alternatives
3. Establishing priorities among elements of the hierarchy
4. Synthesizing
5. Conductivity sensitivity analysis

Optimization of process parameters is important to obtain a desired good quality weld. The different process parameters have significant effect on the quality of weld and their effects are interrelated. Optimization in such case can be quite satisfactorily be achieved by analytical hierarchy process [9].

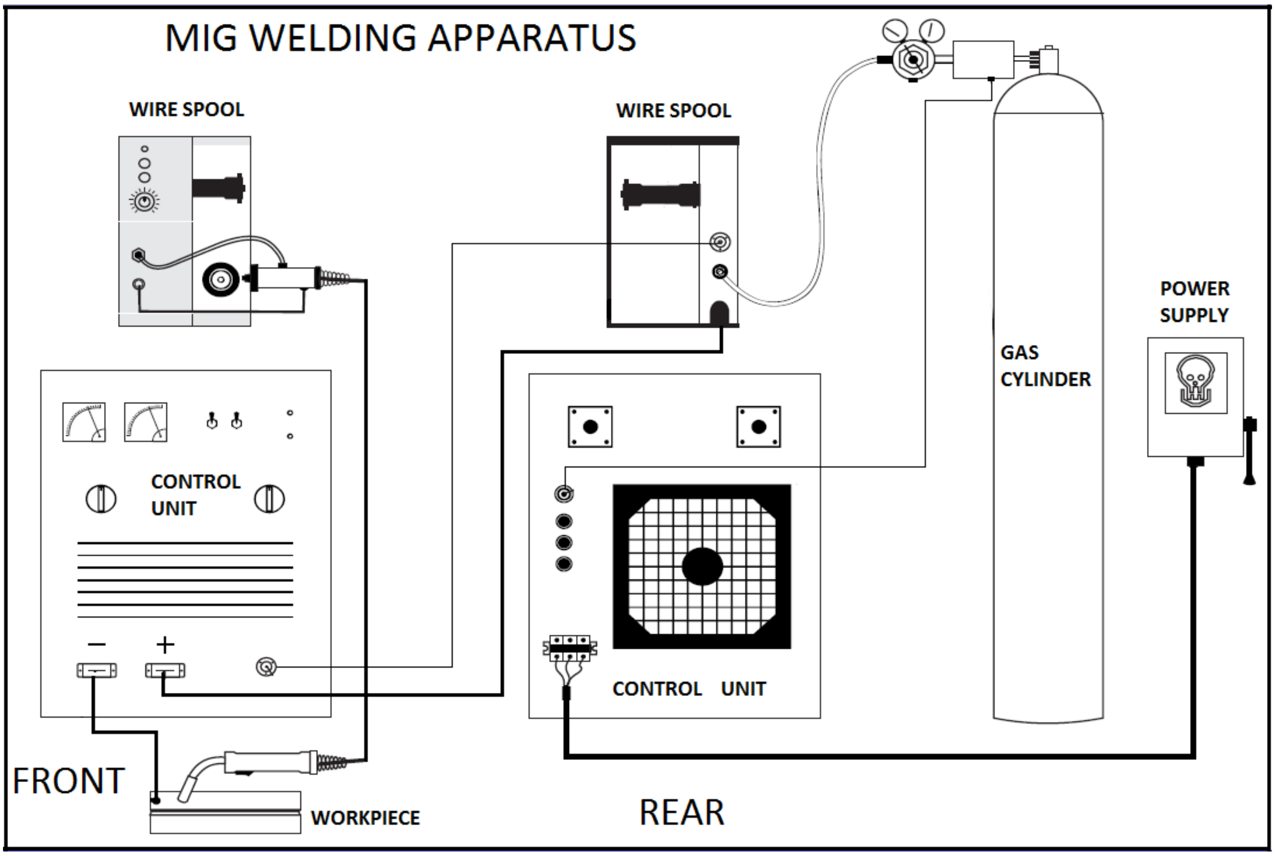
2. EXPERIMENTAL

2.1 Materials

In this experiment low carbon steel (Mild Steel) was used as work piece for welding. To carry out the complete experiment 10 alternative conditions (Table-2) were considered. For each test at least four samples were used. In the MIG welding Argon and CO_2 was used 80%/20% as shielding medium. Commercially available wire electrodes contain deoxidizing metals such as silicon, manganese; titanium and aluminum in small percentages were used to weld mild steel plates.

2.2 Gas Metal Arc Welding

By far most used process for welding gas metal arc welding. It combines speed with versatility and the ability to make high quality welds. The GMAW process is applicable to heavier thickness of metal. This process is applicable to heavier thickness of metal. It is much faster than gas tungsten arc welding (GTAW) [10]. The electrode wire must be clean. It porosity occurs, it is possible that it came from moisture absorbed in the oxide coating of the electrode wire pure argon is normally used for electrode in GMAW. Gas purge control and post gas flow should be used. The angle of the gun or torch is critical; generally it is 30° [11]. The wire feeding equipment for the welding must be in good adjustment for efficient wire feeding. Proper drive rolls should be selected for the size of the electrode wire. The spool gun is used for the small diameter electrode wires [12]. The basic setup of MIG welding is given bellow –



.Figure 1: Experimental setup for MIG welding [13]

The basic technique for GMAW is quite simple, since the electrode is fed automatically through the torch. By contrast, in gas tungsten arc welding, the welder must handle a welding torch in one hand and a separate filler wire in the other, and in shielded metal arc welding, the operator must frequently chip off slag and change welding electrodes. GMAW requires only that the operator guide the welding gun with proper position and orientation along the area being welded. Keeping a consistent contact tip-to-work distance (the *stick out* distance) is important, because a long sickout distance can cause the electrode to overheat and will also waste shielding gas. Sickout distance varies for different GMAW weld processes and applications.

Current, voltage and speed are the principle parameters of gas metal arc welding. Welding current determines the heat, which fuses and penetrates the metal. Voltage or the arc length determines the arc force. With a constant current machine, adjusting the power source sets the current. The arc length is set by adjusting the wire feed speed. Whereas with a constant voltage machine, the current is set by adjusting the wire feed speed and arc length by adjusting the output voltage of the power source. Constant-voltage power and constant speed electrode devices are normally used with small diameter electrodes less than 1.2mm [14]. The electrode feed rate is adjusted to give a spray transfer mode of filler metal. The welding current is set at the desired value, and the arc voltage is set by adjusting the wire feed speed to the desired arc length. The arc length is critical with respect to good penetration with the groove faces. If the voltage is too low, short circuiting will take place between the electrode and the weld pool [15].

2.3 The Analytical Hierarchy process

The analytical hierarchy process (AHP) represents a powerful tool analysis of the multi criteria. Decision problems with the finite set of alternatives .Regarding to the current development of the AHP we can summaries only its main features in this section.

The AHP starts from the fact that decision problems can mostly be organized into a hierarchy. The hierarchy represented a decision problem contains always several levels. The first level defines a main goal of the decision problems and the last level describes usually the decision alternatives. The level between the last and the first level can contains secondary goals, criteria and sub criteria of the decision problem. The number of the level is not limited, but in the typical case it does not exceed 4 or 5 [16]. The tree level hierarchy which can represent the classical decision problem with the finite set of alternatives evaluation of n-alternatives x_1, x_2 - - - - x_n by c- criteria c_1, c_2 - - - - -c_k shown bellow

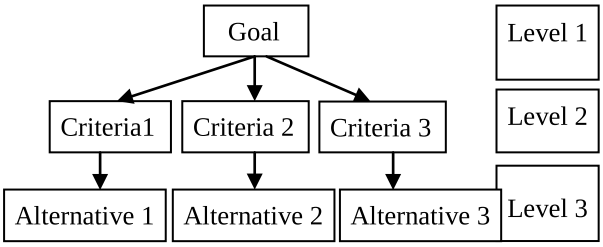


Figure 2: Typical hierarchy structure of the AHP [17].

The ratio scale of comparison matrix is constructed by considering preferential judgment. The experiment is accomplished on the specimen by selecting different alternative conditions such as current, voltage and speed. For optimizing the process parameters of MIG welding the criteria such as filler metal deposition, depth of penetration, height of bid, width of bid, heat affected zone, hardness number are selected. The local weights are obtained by comparing the alternatives for different criteria. Finally the global weights for the alternatives are calculated.

2.4 Experimental Consideration

To find out the outcome of this research 9 Preferential Judgment were considered with different rating 1-9. Depending upon those rating shown in the following table (Table-1) the comparison matrix formed, which needs to proceed towards the goal of this research.

Table.1: Ratio Scale of Comparison Matrix [18].

Preferential Judgment	Rating
Extremely preferred	9
Very strong to Extremely preferred	8
Very strongly preferred	7
Strong to very strongly preferred	6
Strongly preferred	5
Moderately to strongly preferred	4
Moderately preferred	3
Equally to moderately preferred	2
Equally preferred	1

10 alternative conditions were considered to carry out the experiment. At a constant voltage 80V those 10 alternative Conditions (E1-E10) are shown in the following table (Table 2).

Table.2: Alternative Conditions

Alternative no.	Speed (mm/min)	Voltage (V)	Current (A)
1 (E1)	300	80	120
2 (E2)	300	80	220
3 (E3)	300	80	236
4 (E4)	300	80	260
5 (E5)	300	80	276
6 (E6)	420	80	300
7 (E7)	420	80	316
8 (E8)	420	80	332
9 (E9)	420	80	348
10 (E10)	420	80	362

For each alternative conditions different criterion shown in the following table (table-3) were measured and compared to find out the best alternative condition.

Table.3: Condition Selection Criteria

Criterion No.	Criterion
C1	Filler metal deposition rate
C2	Depth of penetration
C3	Height of bid
C4	Width of bid
C5	Heat affected zone
C6	Hardness number

3. RESULTS AND DISCUSSION

For each alternatives filler metal deposition rate, depth of penetration, height of bid, width of bid, Heat affected zone and Brinnel hardness number measured and compared. For 10 alternatives and 6 different criterion comparison matrix formed to find out the local weights and global weights.

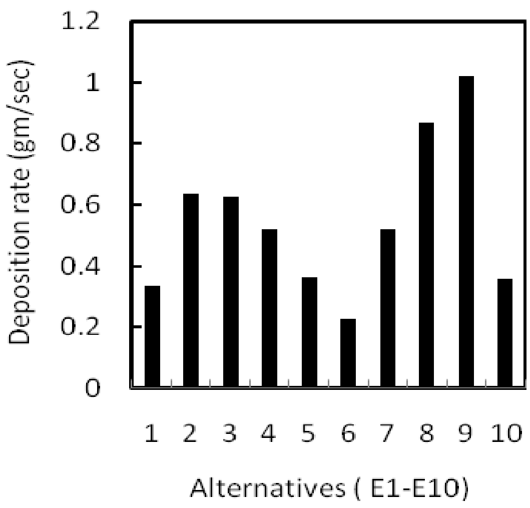


Figure 3: Rate of filler material deposition for different alternatives

Deposition rate of the filler material on the mild steel specimen is higher for the alternative condition 9. From fig.3 it is clear to understand alternative condition 9 is best when higher deposition rate is essential.

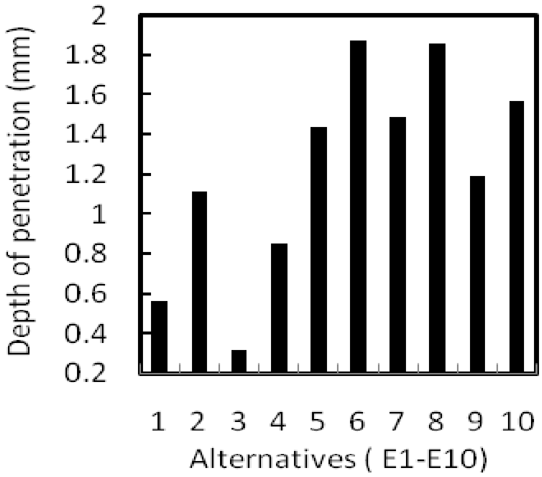


Figure 4: Depth of penetration for different alternatives

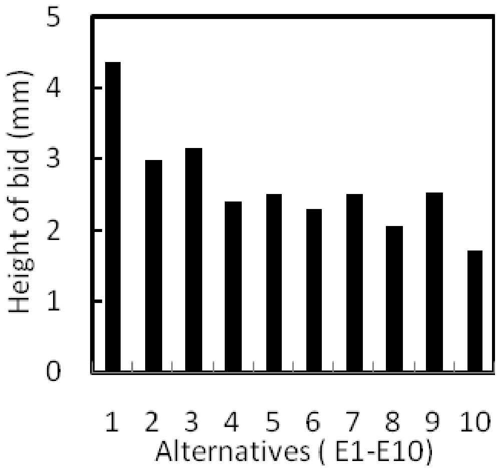


Figure 5: Height of bid for different alternatives

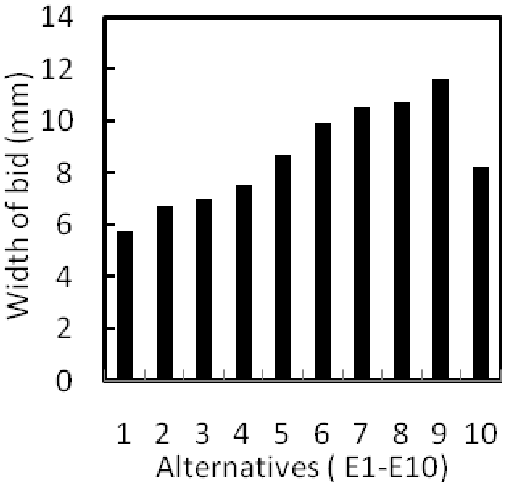


Figure 6: Width of bid for different alternatives

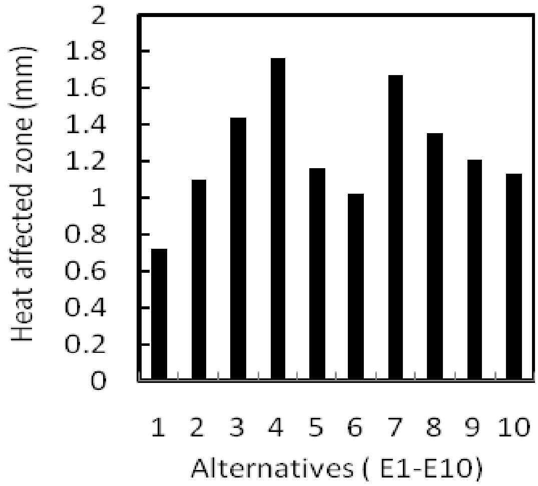


Figure 7: Comparison of heat affected zone for different alternatives

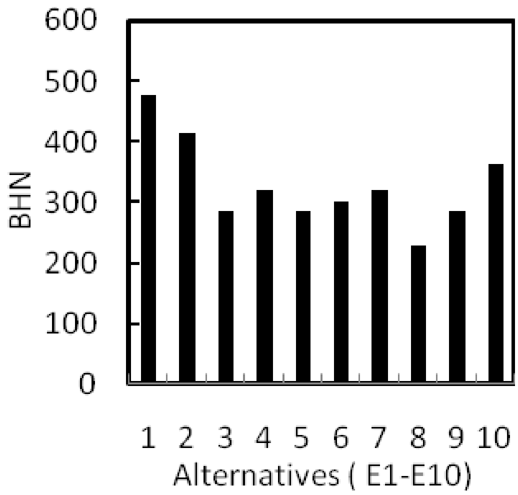


Figure 8: Variation of Brinnel hardness number (BHN) for different alternatives

Similar to the fig. 3 others five criterion varies with different alternatives. In fig. 4, for the alternative 6 depth of penetration is maximum. In fig. 5 height of bid is maximum for the alternative1. Bellow 350 A width of the bid is larger, shown in the fig. 6. When the current is about 250A and voltage is 80V the heat dissipate through the specimen is greater than the other conditions shown in the fig. 7. Hardness of mild steel is always higher at low voltage and lower current. Because at this condition lower amount of heat generated on the specimen. Thus it causes higher hardness on the surface. From the above figures it is hard to conclude what alternative condition is perfect for MIG welding. Though apparently different alternative condition seems to be useful for a particular condition, it needs more steps to know which one is much more close to the goal of this research.

3.1 Local Weights

To find out the better conditions for MIG welding analytical hierarchy process is applied in this research, where the local weights for different criterion is an essential element to conclude the research.

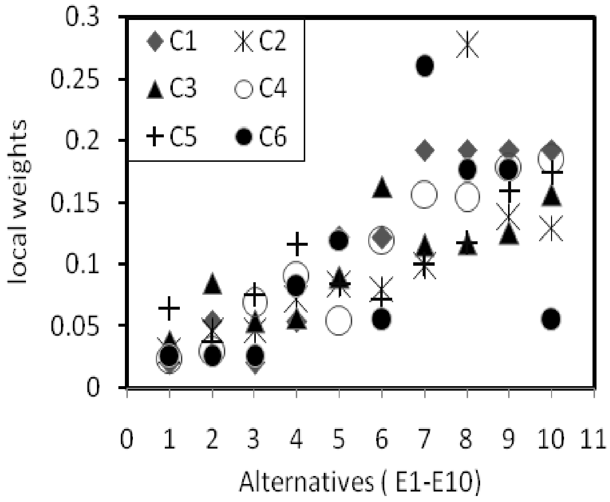


Figure 9: Comparison of local weights for different criterion and for different alternatives

In the fig. 9 for different criteria and alternative conditions the local weights have been plotted. The values of all the points originated from the comparison matrix. In this figure for the criterion number 2 (C2) and the alternative condition 8, the local weight is higher.

3.2 Global Weights for Alternatives

Global weight is the final step to reach to the goal of this research. The overall priorities for each decision alternative can be computed by using the priority for each criterion as a weight that reflects its importance.

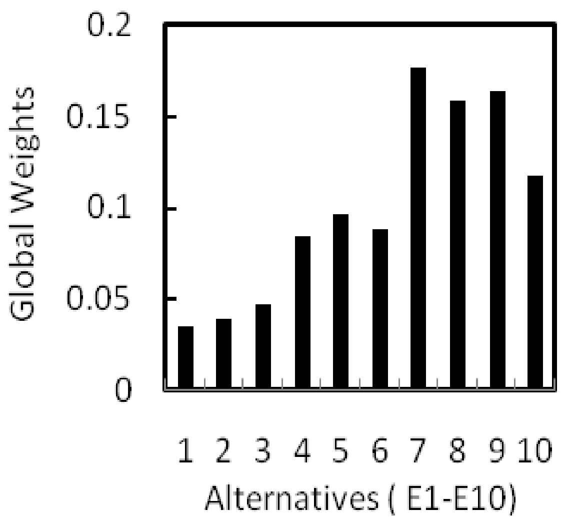


Figure 10: Comparison of global weights for different alternatives

Fig. 10 reflects that the global weight increase with the increase of welding current to a certain level. In this case this level is 316 A, when the voltage is 80 V and the speed is 420 mm/min. i.e. the alternative number 7 shows the higher global weights.

4. CONCLUSIONS

To summarize our experience, the following conclusions can be made.

(a) Since the imperfect definition of factors may cause either difficulty in comparison or omission of information, AHP structure identification and element selection of each hierarchy can hence have a direct effect on the results.

(b) Like other systems analysis methods, AHP still has its limits for application. But nevertheless, the research shows that in dealing with the decision-making problems of a multi-hierarchy system, AHP provides a powerful tool through synthesizing various options and finally gives both qualitative and quantitative analyses, and the process itself is in fact a process of understanding the complex system.

(c) AHP shortfall is always greatest for highest risk levels.

(d) One can use this process to find out proper sets of parameters to have a good welding joint by MIG welding as well as any other processes having large no of parameters.

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