

Optimization of Pulsed Gas Metal Arc Welding Parameters for Fabrication of Austenitic Stainless Steel

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ABSTRACT

Parameters of pulsed GMAW, have a distinct effect on the characteristics of the weld viz., the stability of the arc, weld quality, bead appearance and weld bead geometry. Improper selection of these pulse parameters may cause weld defects including irregular bead surface, lack of fusion, undercuts, burn-backs and stubbing-in. Therefore, it is important to select a proper combination of parameters of the pulsed current for welding, which will ensure that the process gives proper results in all the above aspects. But achieving such a combination of welding parameters without a concrete base has a fairly low probability of achieving the desirable weld properties due to the complexity and interdependence of pulse parameters involved in this process. Efficient use of statistical Design of Experiments (DOE) such as Response Surface Methodology incorporates a scientific approach to the welding procedure development. This paper represents a detailed study on various aspects of gas metal arc welding, the effect of pulse parameters and the methodology used for selecting the range of these parameters.

Key Words— P-GMAW, thermal Pulsing, austenitic stainless steel, SS 347

I. Introduction

Gas Metal Arc Welding (GMAW), by definition, is an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously fed filler metal electrode and the work. The process uses shielding from an externally supplied gas to protect the molten weld pool.

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 work piece metal(s), which heats the workpiece metal(s), causing them to melt and join. Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. 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.

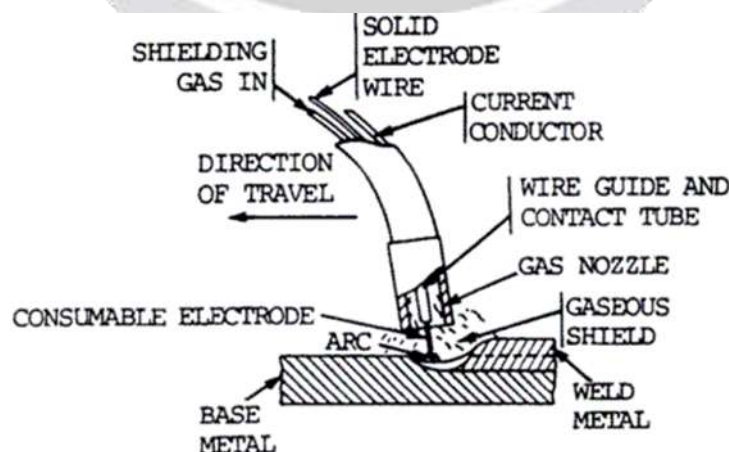


Fig.1 Schematic diagram of gas metal arc welding.

Gas metal arc welding was initially developed as a high deposition, high welding rate process having advantage of high welding currents and continuous wire feed. However, in recent years the industries have become more efficient and attempts are made to overcome the limitations of conventional gas metal arc welding which in turn led to the development of pulsed gas metal arc welding (GMAW-P).

II. Literature Review

Palani, P. K., and N. Murugan [4] presented a review on pulse welding parameters and its effect on welding characteristics such as arc stability, weld quality, weld bead appearance and weld bead geometry. Ghosh, Prakriti Kumar, et al. [1] studied the performance of conventional Gas Metal Arc Welding (GMAW) and Pulsed Gas Metal Arc Welding (P-GMAW) processes with respect to the heat input. The results showed that P-GMAW was superior to conventional GMAW at low heat input. Yi, Luo, et al. [2] used structure-borne acoustic emission signals to study the effect of welding heat input to metal droplet transfer. Subramaniam, S., et al. [9] used statistical experimental design to identify power supply pulsing parameters for pulsed gas metal arc welding. Wire feed rate, peak current, background current, duty cycle and pulsing frequency are the primary parameters identified.

III. Pulsed Gas Metal Arc Welding (GMAW-P)

Pulsed spray metal transfer, known by the acronym GMAW-P, is a highly controlled variant of axial spray transfer, in which the welding current is cycled between a high peak current level to a low background current level. Metal transfer occurs during the high energy peak level in the form of a single molten droplet.

The welding current alternates between a peak current and a lower background current, and this controlled dynamic of the current results in a lower average current than is found with axial spray transfer. The time, which includes the peak current and the background current, is a period, and the period is known as a cycle (Hz). The high current excursion exceeds the globular to spray transition current, and the low current is reduced to a value lower than is seen with short-circuiting transfer. Ideally, during the peak current, the high point of the period, a single droplet of molten metal is detached and transferred across the arc. The descent to the lower current, known as the background current, provides arc stability and is largely responsible for the overall heat input into the weld. The frequency is the number of times the period occurs per second, or cycles per second. The frequency of the period increases in proportion to the wire feed speed. Taken together they produce an average current, which leverages its use in a wide material thickness range.

Components of Single Pulsed Event in P-GMAW process: [12]

1. Front Flank Ramp-Up Rate:

The ramp-up rate determines how rapidly the current will increase from the background current to the peak current. The ramp-up rate assists in the formation of the molten droplet at the end of the electrode. The rate is measured in terms of amps/millisecond.

2. Overshoot: Overshoot describes the condition where the front flank increases to a predetermined level beyond the level of the peak current. It is expressed in units of percent. Increasing overshoot is associated with a more rigid arc that is less prone to deflection.

3. Peak Current:

Peak current is the nominal current for the high energy pulse. It is adjusted to a level that is set consistently above the globular to spray transition current. Peak current is expressed in units of ampere. During the time when the peak current is delivered, the molten droplet detaches from the electrode. An increase in peak current increases the average welding current and the weld penetration.

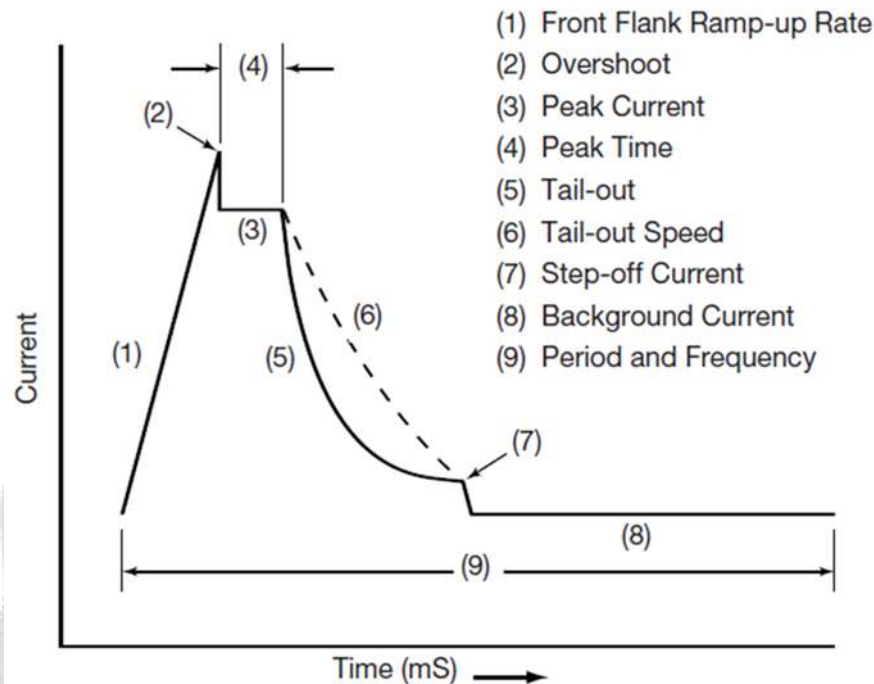


Fig 2. Single pulsed event components of P-GMAW [12]

4. Peak Current Time:

Peak current time describes the length of time that the current is at its peak. It is associated with droplet size. Peak time is expressed in terms of milliseconds. As the peak time increases, the droplets decrease in size. As the peak time decreases, the droplet size increases.

5. Tail-Out:

Tail-out is associated with current decay from the peak to the background current. The increase in tail-out time increases the average current and marginally increases penetration. Tail-out time is increased to provide an increase in droplet fluidity.

6. Tail-Out Speed:

Tail-out speed defines the rate at which the waveform moves from the peak current to either the step-off current or the background current.

7. Step-Off Current:

Step-off current defines the current level at the portion of the waveform where tail-out ends. It can add to, or take away from, the area under the waveform. It is associated with stabilizing the arc.

8. Background Current:

Background current refers to the lower nominal current of the output. The unit of measure for the background current is ampere. Increases in background current will increase penetration.

9. Pulse Frequency:

Pulse frequency is responsible for how often the pulse cycle occurs in one second. As the frequency increases, the arc narrows, the average current increases, and the molten droplets become smaller. As the frequency decreases, the weld bead and the arc become wider. Frequency is generally proportional to the wire feed speed.

IV. Experimental procedure

A Design of Experiment of three factor was created using Minitab-17 software. A response surface design having a total of 6 center points, 4 cube points and 2 axial points was created. The parameter range is as shown in the table.

Input Parameter	Range
Current (Amp)	140-160 (amp)
Thermal Frequency (Hz)	2-3 (Hz)
Travel Speed (mm/min)	200-300 (mm/min)

Table 1: Input parameters and its range

i. Current:

Here the current that is taken into consideration for the input parameter is the mean current/average current. The average current can be calculated by the following equation:

$$I_m = (I_p T_p + I_b T_b) / (T_p + T_b) \text{ amp [4]}$$

Where,

I_m – mean current,

I_p – pulse current,

I_b – background current,

T_p – Duration of pulse current,

T_b – Duration of background current

ii. Thermal Frequency:

The low frequency pulsing of the filler wire which is used for the improved control over the weld pool. In MIG welding the wire feed speed is pulsed with a frequency in the range of 1 – 10 Hz. [11]

iii. Travel Speed:

Amount of actual length covered during welding per unit time is known as travel speed. Here it is measured in terms of mm per minute.

Austenitic stainless steel SA240 Type 347 is used as the base material and the welding of the test coupons is carried out using ER347 type of consumable. The chemical composition of both, the base material and the consumable is according to ASME SEC-II standards.

Other parameters such as Voltage, Arc length, gas flow rate, shielding gas composition, etc. are kept constant while designing the experiments.

V. Experimental work

Once the parameters and its range is entered into the software (Minitab-17), output is obtained in the form a table as shown below. This table was generated using Response Surface Methodology (RSM) and central composite design. Tensile testing of the base metal and the transverse weld joint having weld at its center was carried out by using flat tensile specimens. The value of Tensile Strength is measured in terms of MPa.

The following table shows the result of tensile strengths that are obtained with respect to the given combination of the welding parameters.

Run Order	Current (Ampere)	Wire Pulse Frequency (Hz)	Travel Speed (mm/min)	Tensile Strength (MPa)
1	140	2.0	200	603.0
2	160	2.0	200	504.9
3	140	3.0	200	520.4
4	160	3.0	200	588.7
5	140	2.0	300	501.0
6	160	2.0	300	602.0
7	140	3.0	300	511.0
8	160	3.0	300	598.2
9	150	2.5	250	618.0
10	150	2.5	250	621.4
11	150	2.5	250	617.0
12	150	2.5	250	616.9
13	133.67	2.5	250	498.6
14	166.33	2.5	250	555.2
15	150	1.68	250	613.5
16	150	3.31	250	598.2
17	150	2.5	168.35	589.9
18	150	2.5	331.65	507.8
19	150	2.5	250	618.0
20	150	2.5	250	620.8

Table 2: Tensile strength results obtained for each combination of parameter.

VI. Result and discussion

According to ASME Sec-IIA the minimum tensile strength for SA240 Type347 material is 520MPa. Hence the welding parameter combination that results in lower tensile strength is considered unacceptable. From table 2 it is observed that the maximum tensile strength obtained is 621.4MPa while the minimum is 498.6MPa. This shows that tensile strength of the material is dependent on the heat input which is a function of current and travel speed. Where the heat input can be calculated from the following equation:

$$\text{Heat Input (J/cm)} = \frac{\text{Welding Current (A)} \times \text{Arc Voltage (V)}}{\text{Welding Speed (cm/s)}}$$

From the above equation it can be said that heat input is directly proportional to the welding current while inversely proportional to the travel speed. Heat input increases with the increase in current, while it decreases with the increase in travel speed. One has to select optimum parameters in order to have sufficient amount of heat input required to perform the welding.

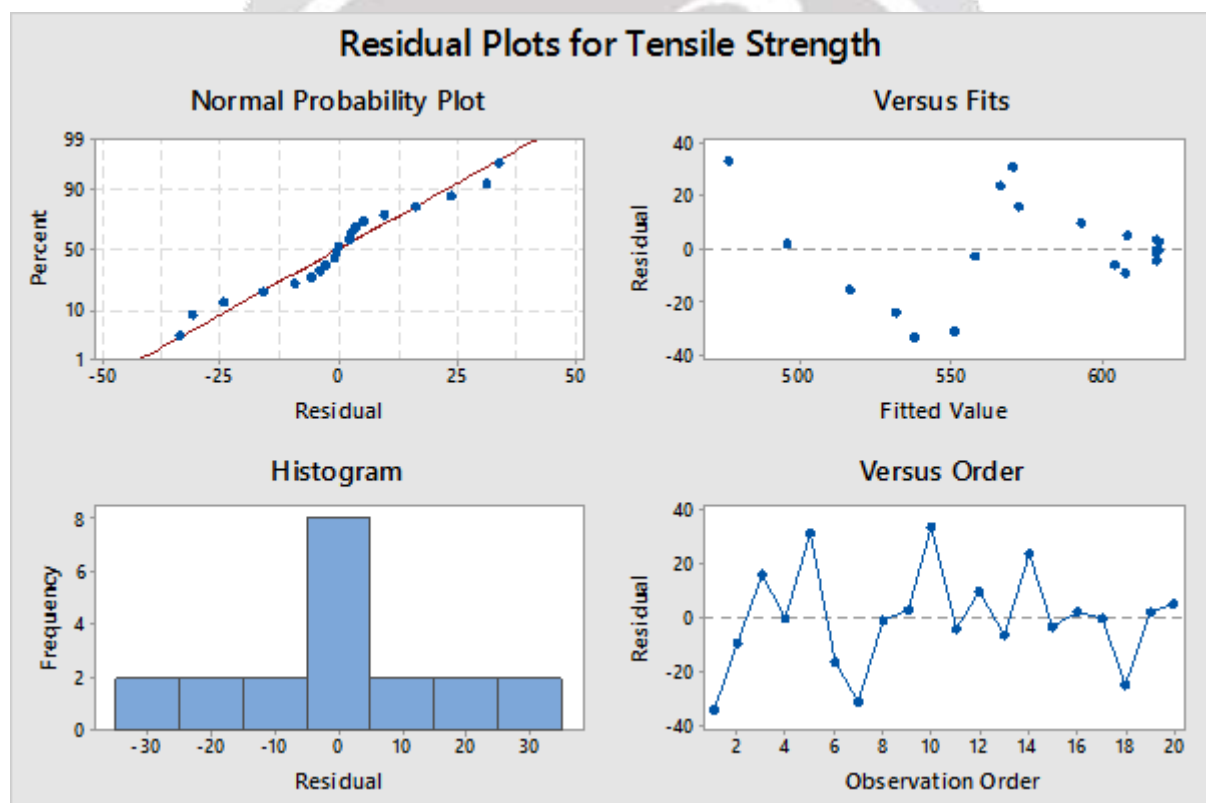


Fig. 3 Residual plots for Tensile strength

The above graphs are residual plots for tensile strength obtained with the help of response surface methodology. These graphs shows that the actual values and the predicted values are very close.

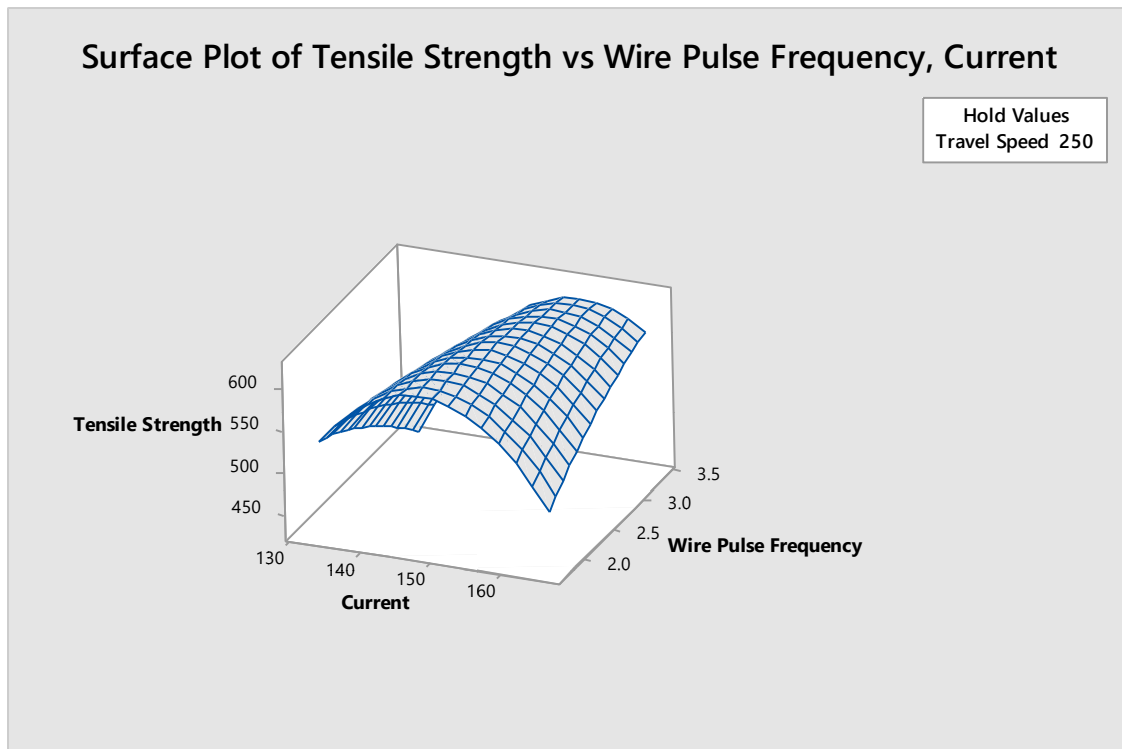


Fig. 4: Surface plot of tensile strength vs WPF & Current

The above graph shows that the value of tensile strength is maximum when the current parameter is near 150A. Also it is seen that tensile strength value decreases with the decrease in wire pulse frequency while it is not much affected when the pulse frequency is increases above 2.5 Hz.

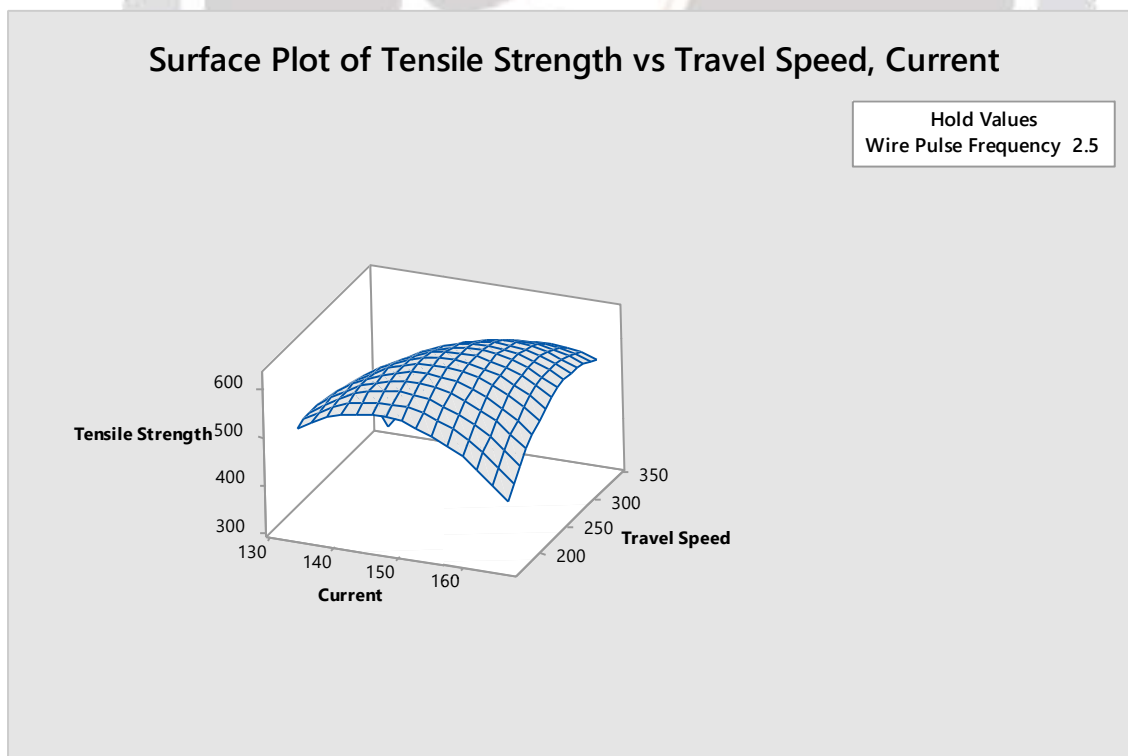


Fig. 5: Surface plot of tensile strength vs Travel speed & Current

As shown in the graph the tensile strength is maximum when the current is 150A and the travel speed is 250mm/min.

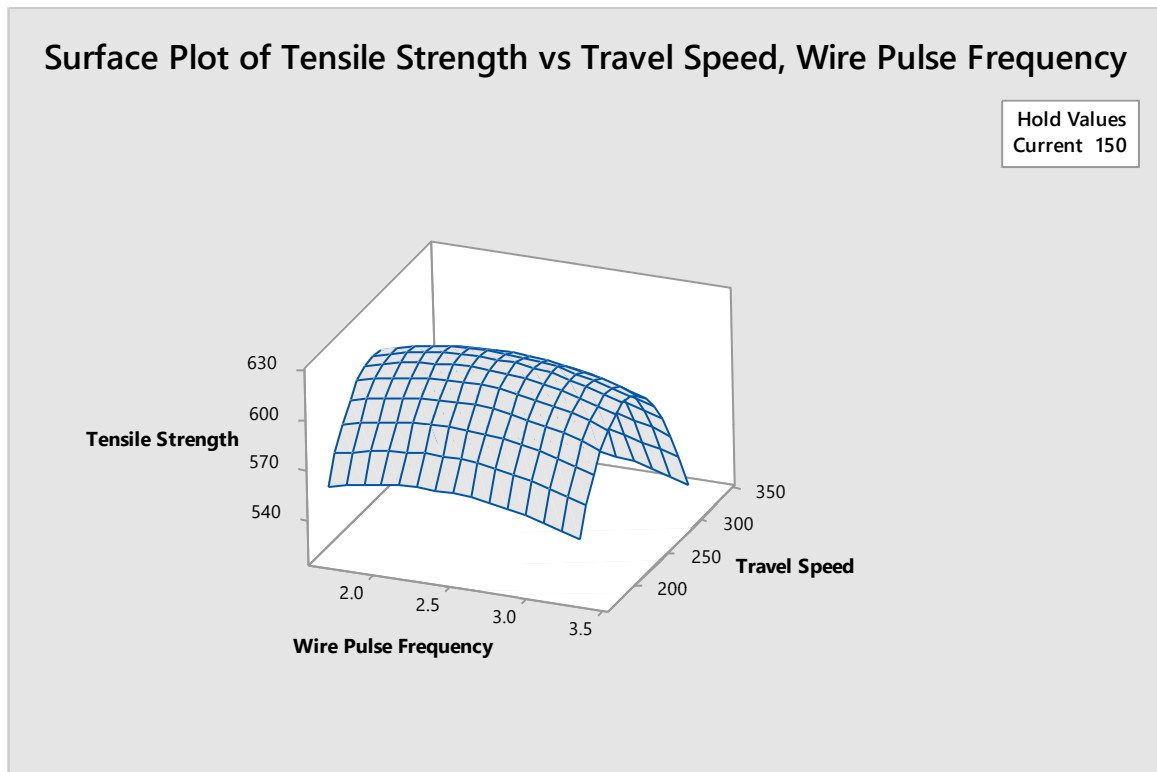


Fig. 6: Surface plot of Tensile strength vs Travel speed and WPF

The above graph shows that the tensile strength decreases with the decrease in the wire pulse frequency and travel speed.

VII. Conclusion

From the above results we can conclude that:

- i. Out of all the parameters the current and travel speed plays a significant role in determining the tensile strength of the weld.
- ii. Thermal frequency helps to reduce overall heat input which leads to a finer grain size.
- iii. Maximum tensile strength is obtained when current is 150Amp, thermal frequency is 2.5Hz and the travel speed is 250mm/min.
- iv. In comparison to conventional GMAW process P-GMAW has low average current and hence welding of thin materials is possible.

VIII. References

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