A review of Pulse current gas tungsten arc welding for different alloys

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Abstract

Pulse current gas tungsten arc welding is an important joining technique for different metals like Aluminium, Magnesium, Steel, Titanium and their alloys. With increasing application of these metals and alloys in aerospace, aircraft, automotive, electronics and other industries PTIGW is the best technique evolved so far. In this document an attempt has been made to critically review this welding technique from different perspective for different metals and alloys. Some important PTIGW processing parameters and their effect on weld quality are discussed. The microstructure and metallurgical defects encountered during welding process such as porosity, cracking, oxide inclusions and loss of alloying elements are described. Mechanical properties of welds such as hardness, tensile and fatigue strength, and other important structural properties are discussed. The aim of the report is to review the recent progress in PTIGW of different metals and alloys and to provide the basis for follow-on research.

1. Introduction

Reduction of mass is a prime concern for many industries involved in making household appliances and transportation. Therefore the selection of metals and its alloys on the basis of properties suited to different industries has become significant. Hence the focus on lightweight materials like aluminium and magnesium and other corrosion resistant materials like steel and titanium has become predominant [1]. Aluminium based alloys have been widely used in automobile structures due to their unique property such as high strength to weight ratio. Although large scale production of these metals will not be feasible in near future, there is no doubt that the use of these metals and alloys based material will be increasing steadily. Metals and its alloys can be joined by most fusion and solid state welding processes, as well as by brazing and soldering. Fusion welding is commonly done by GMAW (Gas Metal Arc Welding), GTAW (Gas Tungsten Arc Welding) and resistance spot and seam welding. Plasma and Electron Beam Welding are used in special applications. SMAW (Shielded Metal Arc Welding) and oxy-fuel gas welding may be used for applications where high strength and quality are not much of the interest. Two welding process mostly used for Al, steel, Mg and titanium are GMAW, and GTAW. GTAW was the first arc welding process applied to aluminium [2]. It produces very attractive welds, with good profile and bright appearance. GTAW welding, often requiring hand fed filler rod to build up the weld deposit. In GTAW welding technique the tungsten electrode is used to strike arc and melt the base metal where welding is to be done.

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2. Pulse TIG Welding

This is modified version of TIG welding in which the welding current (DC) is supplied in form of pulses. The pulsed current alternates between a low or background level and peak level. The duration and amplitude of both peak and background currents can be varied independently to suit the job. The melting takes place during peak current period, and the weld pool solidifies between pulses as the heat is dissipated in the job during the background current period [3]. This current pulsing leads to intermittent melting along the joint seam, giving a series of discrete melt spots, which overlap each other [4]

3. Advantages of the Pulse TIG welding

- It tolerates variation in the fit-up or clamping.
- It permits welding of sheets down to 1 mm with ease, which is normally difficult by standard TIG process.

- It minimizes distortions owing to controlled heat input.
- It makes positional welding easy.
- It requires less operator skill as compared to the normal TIG process.
- It shows marked improvement in weld quality.
- The strong electromagnetic forces developed by the high pulse of current agitate the weld puddle and therefore eliminate weld porosity and thorough root fusion[5].

4. Pulse TIG welding on Aluminium Alloys

Senthil Kumar et.al [6] studied the influence on the tensile properties of AA 6061 aluminium alloy and found out that factorial experimentation technique is more convenient to predict the effect of pulsed current welding parameters on tensile properties of AA 6061 welded aluminium alloy joints. Investigation shows that peak current and pulse frequency are directly proportional to the tensile properties of the welded joints. Study also revealed that base current and pulse on time is having inversely proportional relationship with the tensile strength.

Sanjeev Kumar [7] explored the possibility of welding higher thickness aluminium plates of 6mm. Experimental investigation revealed that tensile strength of the joint has been found to be comparable with DC current, when prepared at some gas flow rate i.e. 7 litre/min. It was also found that tensile strength is optimum at pulse current of 250 Amp and gas flow rate of 15 litre/min and base current 200 Amp.s. It has also been observed that shear strength varies with change of pulse current. Microstuctural studies of weld deposit shows two distinct zones, co-axial dendrites adjacent to fusion line and the fine equiaxed grain in the region of weld center.

Kumar and Sundarrajan [8] attempted to optimize the pulsed TIG welding process parameters of AA 5456 Aluminium alloys welds for increasing the mechanical properties. Experiments were conducted to find out influence of pulsed welding parameters such as peak current, base current, welding speed and frequency on mechanical properties such as ultimate tensile strength, yield strength, percent elongation and hardness of AA 5456 Aluminium alloy weldments. Experimental results showed that there is 10-15% improvement in mechanical properties after planishing. Metallographic analysis further revealed the fine grain structure at the weld centre, which resulted in higher mechanical properties.

Karunakara and Balasubramanian [9] studied the effect of pulsed current on temperature distribution, weld bead profiles and characteristics of gas tungsten arc welded aluminium alloy joints and found out that pulsed current welding technique records lower peak temperatures and lower magnitude of residual stresses compared with constant current welding, which is highly preferable for thin sheet welding. Results further revealed that joint produced by gas tungsten arc welded aluminium alloy exhibits superior tensile properties compared with constant current welding technique. Research further pointed out that the formation of finer grains caused by pulsed current is the main reason for enhanced tensile and hardness properties of the joints.

Laiping et.al [10] developed the model of welding pool surface reflectance of aluminium alloy. Study showed that during welding, surface height of welding pool plays an important role in precise control of welding process. Surface reflectance model of welding pool was built after the analysis of arc intensity, filter system, shape and reflectance characteristics of welding pool and camera parameters which was based on predictions of weld pool characteristics.

5. Pulse TIG welding on Steel alloys

Lothongkum et.al [11] studied the effect of PTIGW parameters on the delta-ferrite content, shape factor and bead quality in the orbital welding of AISI 316L stainless steel plate. The experimental results clearly revealed that increasing welding speed will increase the pulse current. Further they also observed that while increasing the nitrogen content in argon gas decreases the pulse currents, and due to this the solubility of nitrogen in the weld decreases. Researchers found out that from the 6 to 12 h welding positions the pulse currents decrease to be a minimum at 9 h welding position and increase again at 12 h welding position. Delta-ferrite content also observed in the weld ranges from 6 to 10 % by volume.

Lothongkum, Chaumbai and Bhandhubanyong [12] explored the possibility of PTIGW of 304L austenitic stainless steel in flat, vertical and overhead positions. Researchers sucessfully identified the PTIGW parameters at three different positions with nitrogen content of 0-3% (v/v) in the argon which is used as a shielding gas and same nitrogen content in argon was also enough to control the delta-ferrite content which is often accepted in range of 3-12% (v/v). The welding speed in those positions was found to be 3.4 mm/s at 55% on-time with fixed pulse and base currents.

Madadi et.al [13] explored the deposition process of stellite 6 on plain carbon steel plate using PTIGW cladding process and experimental facts revealed that the central composite rotatable design technique with five-level, full-factor full-factorial design matrix and mathematical models was used to predict hardness and dilution of satellite 6 on carbon steel with high accuracy. Results also indicated that the parameters chosen were significant in clad dilution. Further, welding current found out to be effective parameter which influences heat input and melting and dilution.

6. Pulse TIG welding on Titanium alloys

Balasubramanian et.al [14] attempted to develop mathematical models to predict grain size and hardness of PTIG welded Ti-6Al-4V alloy and found out that procedure is limited to the range of factors considered for investigation. The model developed can also be effectively used to predict the hardness and grain size of titanium alloy within the range of parameters.

Some researchers [15] performed the experimental study to understand the effect of process parameters of PTIG welded titanium alloy and results reveals that four important process parameters of PTIGW were used to optimize the three quality characteristics of tensile properties. Further, the experimental investigation showed that pulse frequency is having greater effect on the multiple quality characteristics of the tensile properties.

Some researchers [16] studied the effect of PTIG on corrosion rate of titanium alloy. It was observed that effect of pulse frequency and peak current had two regions with initially decreasing the corrosion rate and then increasing the corrosion rate irrespective of changes in the base current and pulse on time. Further investigations revealed that the grain refinement has taken place which resulted in increase in corrosion resistance. Study also revealed the parameters which mostly influence the corrosion properties of titanium alloy were peak current and pulse frequency.

Some researchers [17] studied the effect of microstructure on the impact strength of PTIG welded α-β titanium alloy. It have been found that Impact toughness of the joints is having inversely proportional relationship to grain size. Further study revealed the parameters which mostly influence the grain size effect on impact strength are peak current and pulse frequency.

Some investigators [18] studied the effect of PTIGW parameters on Ti-6AI-4V titanium alloy and it was observed that effect of pulsing frequency and peak current had two regions with initially increasing the tensile properties irrespective of changes in base current and pulse-on-time. It has been observed that the main reason of increased tensile property at weld fusion zone is due to grain refinement. Further the value of optimum frequency at which tensile properties are maximum has also been determined.

7. Pulse TIG welding on Magnesium alloys

Roze et.al [19] developed the empirical relationship to predict tensile strength of PTIG welded AZ61A magnesium alloy by incorporating process parameters such as pulse current, base current, pulse frequency and pulse on time. Different statistical tools such as design of experiments, analysis of variance, and regression analysis were used to develop the relationships. Further the effect of pulse current on AZ61A magnesium alloy was studied and experimental results revealed that effect of peak current and pulsing frequency initially increasing the tensile properties and then decreasing the tensile properties irrespective of changes in base current and pulse on time. Study also revealed that pulse current was more sensitive than the other parameters such as pulsed on time, pulse frequency and base current.

Padmanaban et.al [20] compared the fatigue crack growth behaviour of AZ31B magnesium alloy welded by three techniques i.e PTIGW, Friction stir welding (FSW), Laser beam welding (LBW). It was found that laser beam welded joints offered better resistance against the fatigue cracks as compared to FS and PTIG welded joints. Fine grains were observed in weld region and higher hardness was observed in fusion zone. It was also observed that precipitates and favourable residual stress field of the weld region are the main reasons for superior fatigue performance of laser beam welded joints of AZ31B magnesium alloy.

8. Conclusion

PTIG welding is probably an important joining technique for different metals and alloys and can promote their wider uses in aerospace, aircraft, automotive, electronics and other industries. This review explores the effect of some influencial parameters of PTIGW process which effects tensile strength and bead geometry of the joint being fabricated by this process. In the future scientific investigation is still needed to understand and overcome these basic weldability problems like distortion and warpage of metals and alloys.

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