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Pulsed TIG Welding – A Review

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Abstract

GTAW (Gas Tungsten Arc Welding) or TIG (Tungsten Inert Gas) Welding is one of prime welding process which plays a vital role in most of the fabrication industries to weld various metals grades with various parameters. This TIG welding is most preferred because of the better joint which is produced during the process. Recent days new hybrid TIG like pulsed TIG, pulsed synergic TIG etc, comes into practice based on the applications. These TIG Welding variations comes into play because it increases the quality of weld furthermore by changing the various parameters like background current, voltage and control the heat that is generated over the process. In this paper, Pulse TIG is discussed to create an overall idea.

Key words: Pulsed TIG, Weld Quality

1. INTRODUCTION:

The second half of the past century was marked by major advances in the field of microelectronics. The application of this technology to welding sources has allowed, among other things, the development of electronic sources that are able to more efficiently control the welding variables, in particular the welding current. According to Kumar et al. (2007), the higher level is adjusted during the peak period to promote the proper formation of a molten pool, whereas in periods of background power the current is maintained at low levels, just enough to ensure that the extinction of the arc will not happen and allowing the cooling of the molten pool. According to Wu et al. (1999) the reason why pulsed current TIG welding results in a finer grain structure in the weld pool is due to thermal cycle on the surface of the work piece caused by the current pulse. According to Sundaresan et al. (1999) it promotes the continuous change in the weld pool shape and the periodic interruptions in the solidification process. Among the few studies in the literature wherein this theme is addressed is the work of Omar and Lundin (1979). Here, the authors conclude that the mean welding current is the control parameter and they include the pulse variables that act on the efficiency of fusion and penetration. However, although it is a controversial topic, works of this nature are not easily found in the recent literature. This is evidenced by Kumar et al. (2007) who, in a report on the use of pulsed TIG process in aluminum welding, comment on the scarcity of studies on the topic of the pulse parameters. When we analyze the titanium alloy plate, it has low density and high temperature with good resistance against corrosion. In many studies,

1.1 WHY PULSE:

The advantages of pulsed DC TIG are best realized when welding metals which readily melt and flow, such as stainless steels (one possible exception being very thin, e.g. 0.05 mm sections and convolutes for edge welded bellows which are often better welded without pulsing). The aim of pulsing is mainly to achieve maximum penetration without excessive heat build-up, by using the high current pulse to penetrate deeply and then allowing the weld pool to dissipate some of the heat during a proportionately longer arc period at a lower current. Modern power sources provide a square waveform for the pulse cycle. In the USA the low level time B is sometimes known as the keep-alight period, an apt term. Thicker metals, say above 1. O mm, generally require a lower pulse rate than thin metals but the rate should always be what best suits a particular application. Trial and error is still the order of the day. Pulsing can be defined as the consistent overlapping of progressive series of spot welds. There are no rules governing pulse rate but some starting point is necessary. For stainless steel welding with a closed butt seam, a good average pulse ratio would be 1 high to 3 low: in other words, A = 25%B = 75% whilst C = 66% and D = 53%, a ratio of 2 to 1. Then vary the current proportionately up or down until the required weld is achieved. It has been previously mentioned that most pulsed welding is used in automated systems as these give consistent pulse overlaps. To achieve overlap consistency, the means of moving either the torch or the weldments along the seam must be both smooth and step less which gives the seam a not unattractive fish scale appearance and 5.4.Variations in motion cannot be tolerated particularly in precision welding as such variations increase heat input to the spots, spoiling both the strength and the cosmetic appearance of the finished weld.

One other advantage of pulsing is that the pulse action agitated stirs the weld pool bringing impurities to the surface thus reducing inclusions and porosity

TIG pulse soldering for thin metals such as aluminum is most often done and can also be used for copper and various types of steel. A foot pedal or a configuration on a TIG welder can be used for pulsing, but when should you use a pulse. There are some very specific applications for TIG solder pulse and then sometimes it can just be useful to do a better job. See a few pulse implementations for TIG welding. Greater heatpulse control for TIG improves your control if you're not going to burn your metalwork. The heat can be moderated when you solder with the pedal or setting up the pulse to ensure enough heat is present at the joint without placing a ton of filler metal in the joint or burning through the metal. Too much metal in a welding joint could cause headache in your soldering project because it needs to be stopped and cleaned before welding is restarted. The pulse configuration allows you to control the welding process far more without compromising your weld strength and integrity.

1.2 WHEN YOU NEED A NEAT WELD

To drive your weld, a smooth, clean solder for a TIG welding application is a simple way to create. Getting yourself in a steady pulsing rhythm is an ideal way to keep moving the puddle forward or walking the cup along a weld joint TIG welding is most often used when there is little margin for error and the metal is especially thin. By pulsing along the weld joint you can moderate the amount of filler metal you add so that it's evenly distributed and you create a great looking weld.

1.3 MINIMAL MOVEMENT

If you’re in a tight spot and you don’t have a lot of room to maneuver, pulsing your TIG welder is one way to glide along the weld joint, adding filler metal as you go, without worrying about introducing too much heat and filler. The main thing for this application will be a steady hand on the torch and an even pace for the filler metal. If this is a particularly tight spot, you can pick up shorter torches that have a very small head and can fit in a variety of spaces. With TIG welding you can reach a tight spot much better than with a stick welder and you can control the input of filler metal better than with MIG, making it a great option when welding is particularly challenging.

Moving Faster with High Speed Pulse Given some practice, many welders can effectively weld at the high speed of 150 pulses per second, creating neat welds in far less time. While you wouldn’t want to try a faster pulsing speed if you’re not used to it, many welders prefer to move either really slow or really fast in order to create a steady rhythm. Pulsing at around 20 per second has led some welders to make uneven, spotty welds.[1-5]

This would be especially useful in a fabrication shop where you’re seeing a lot of the same metal work pieces over and over and over again. If you have a handle on how fast you need to move on each piece, then there’s a good chance you can bump up the pulsing rate to improve your welding speed. [6-9]

1.4 WELDING ALONG AN EDGE OR A HOLE

If you want to make a quick, clean weld with filler metal without damaging or filling your hole, pulsing is another great way to ensure additional control and precision in a hard welding position. If you don't have a good pulse when you weld TIG, the heat can build up and start melting the metal.

2. REVIEW ON VARIOUS EXPERIMENTS:

The paper of prof. G .Lothongkum and P. Chaumbai has said that The mixed gas after the mixer M1 was split to flow in the root shielding gas line with rate of 8 l/min and flow in the arc shielding gas line with rate of 16 l/min. The% on-time nitrogen content in the argon shielding gas was calculated in volume percentage. The chemical composition of the 304L stainless steel sheet of 3 mm in thickness used in these experiments.. An all-round turn table welding table, self-assembled, with a speed controller was used for adjusting the welding positions and the welding speed. The welding machine was of constant current AC/DC type. Samples of sizes of 100 mm*125 mm*3 mm with square-edge but joints were prepared from stock plate, installed on the welding table and welded with the planned parameters such as welding speed, base and pulse current. The accepted weld bead samples were examined by radiographic tests for porosity and prepared for metallographic observation and study. Only weld metal was machined to small pieces for the analysis of the nitrogen contents by a nitrogen determinate. The weld metal d-ferrite contents were calculated using the quantitative metallographic method.[10-13]

The paper of Correlation of microstructure with mechanical properties of TIG weldments of Ti–6Al–4V made with and without current pulsing states that pulsed current TIG welding offers opportunities to refine the fusion zone microstructure by changing weld pool solidification conditions [4]. In pulsed current TIG welding, arc current varies with time as a square wave, characterized by peak and background currents (Ip, Ib) and their durations (Tp, Tb). Weld beads with a wide variety of sizes, shapes and microstructures can be deposited by appropriate selection of these parameters. Metallurgical advantages of pulsed current welding frequently reported in the literature include refinement of fusion zone grain size and substructure, reduced width of the heat affected zone, control of segregation, etc. 1.9 mm thick sheet of Ti–6Al–4V received in the form of α–β processed and mill annealed condition was used in the present investigation. The chemical composition (wt. %) of the material was 6.01 Al, 4.01 V, 0.14 Cr, 0.13 Fe, 0.008 H, 0.01 C, 0.004 N, 0.114 O and balance Ti. Coupons of size 173×68×1.9 mm cut from the sheet were mechanically wire brushed, acid pickled in an HF solution and cleaned with acetone prior to welding. polished and etched in a solution of 2% HF and 3% HNO_3 in 95% distilled water. For transmission electron microscopic work thin foil specimens were prepared by mechanical thinning followed by electrolytic thinning in a solution of methanol and 10% per chloric acid at −30 °C. Vickers micro hardness measurements were done on the base metal, heat affected zone (HAZ) and weld metal by a diamond pyramid indenter under a load of 500 g for 15 s. Tensile tests were conducted at a constant initial strain rate of 1.33×10-3 s-1 at four different temperatures (25, 150, 300 and 450 °C) on base metal as well as weldments. Tiago Vieira da Cunha Anna Louise explains that welding tests with different current pulse amplitudes (ΔI) were performed. The pulse amplitude corresponds to the difference between the values of the peak and background currents. For that reason, were not used a small background current values only to keep the voltaic arc open, as pointed out in the literature. A mean current value of 150 A was established so that it was possible to achieve peak and background current amplitudes that resulted in an RMS current value approximately 50 A greater than the mean current value. Thus, an RMS current of 150A was established, and the pulse amplitude was set to 40, 120 and200 A. At the higher test pulse (200 A), a mean current value of about 110 A was calculated, in which this 40 A was smaller than the RMS current value. Finally, were used peak time and the background equals to 10 ms, resulting in a pulse frequency of 50 Hz.

In the paper of Optimization of pulsed TIG welding process parameters on mechanical properties of AA 5456 Aluminum alloy weldments sorder to maximize the quality characteristics, the present investigation has been made in the following sequence.

1. Selection of base material and filler material.
2. Identify the important pulsed welding process parameters.
3. Find the upper and lower limits (i.e. range) of the identified process parameters.
4. Select the orthogonal array (design of matrix).
5. Conduct the experiments as per the selected orthogonal array.
6. Record the quality characteristics (i.e. mechanical properties).
7. Find the optimum condition for maximizing the mechanical properties.
8. Conduct the confirmation test.
9. Develop the regression models to predict the mechanical properties within the selected range.
10. Identify the significant factors.
11. Check the adequacy of the developed models.

Selection of base material and filler material

The base material employed in this study is 2.14 mm thick Al–Mg Aluminum alloy welded with 5356 filler material. The chemical composition of the base material and filler material. The selection of the filler material is based on the mechanical properties and resistance to cracking in the weld [6].Identify the important pulsed welding process parameters. The most important process parameters which are having greater influence on the weld bead geometry and fusion zone grain refinement of pulsed welding process have been identified. They are peak current, base current and pulse frequency.

The working range of the process parameters

A large number of trials have been conducted by varying one of the process parameters and keeping the others constant. The working range of peak current, base current, welding speed, pulse frequency has been explored by inspecting bead appearance and the full penetration. The working range of the process parameters selected under the present study and the constant process parameters

Selection of orthogonal array

Number of process parameters considered under this study is four, and the level of each parameter is two. The degrees of freedom of all the four parameters and their interactions are seven. Hence, L8 orthogonal array is selected. Each condition of the experiment was repeated twice to reduce the noise/error effects.

Conduct the experiments as per the selected orthogonal array

The base metal sheets of dimension 250 mm ×150 mm ×2.14 mm have been prepared and butt joints were made using the experimental layout. An automatic TIG welding machine has been employed for conducting the welding experiments. Prior to welding, the base metal sheets were pickled with a solution of NaOH and HNO3, wire brushed, and degreased using acetone and finally preheated to 100 oC. The sheets to be welded were kept on steel backing bar and ends were clamped to maintain the alignment and gap. Purging is provided at the bottom of the sheets. The same argon gas is used for shielding as well as purging. The weld joint is completed in single pass.

Record the quality characteristics (i.e. mechanical properties).

Specimens for tensile testing were taken at the middle of all the joints and machined to ASTM E8 standards [7]. Tensile test was conducted using a computer-controlled universal testing machine with a cross head speed of 0.5 mm/min. All the welded specimens were failed in the weld region. The ultimate tensile strength of the weld joint is the strength of the weld. The regression model selected includes the effects of main factors and first-order interactions of all the factors. Develop the regression models. The responses Y such as ultimate tensile strength, yield strength, percent elongation and hardness are the function of peak current, base current, welding speed and pulse frequency. The regression model selected includes the effects of main factors and first-order interactions of all the factors. Identify the significant factors .Analysis of variance (ANOVA) is applied to find out the significance of main factors and their interactions. In addition, the F-test can also be used to determine which welding process parameter has significant effect on the response (i.e. ultimate tensile strength, yield strength, percent elongation and hardness). Usually, the change of the welding process parameter has significant effect on the response when the F-ratio is large. It is found that the coefficients of the variables and their interactions are significant.

3. REVIEW ON THE RESULTS AND DISCUSSIONS:

In the paper of TIG pulse welding of 304L austenitic stainless steel in flat, vertical and overhead positions describe three different welding speeds of 3.4, 5, 6.8 mm/s were tested. The pulse frequency, pulse currents and base currents will be changed in relation to the welding speed, the pulse frequency, pulse currents and base currents being increased with the welding speed in order to secure similar weld bead profiles and surfaces to those in the case of lower welding speeds. Thistle appropriate pulse frequencies at welding speeds of 3.4, 5and 6.8 mm/s are 1, 1.5±2, and 2 pulse/s, respectively. Summary results of welding with these parameters are smooth rippled surface, a concave surface appearance, too long distance between the peaks of the ripple, occurred. in argon shielding gas, a welding speed of 3.4 mm/s, a base current of 48 A, a pulse current of 185 A, 55% on-time, and a pulse frequency of 1pulse/s. A rippled surface of the weld bead is clearly seen, The weld metal nitrogen content increased from0.06 to 0.15 wt% as the nitrogen content in the argon shielding gas was increased from 0 to 5% (v/v.). (Additional data of welding with 4 and 5% (v/v.) nitrogen content in argon shielding gas was obtained for confirmation. shows the amount of ferrite content with the nitrogen content in the weld metal. The d-ferrite content in the weld metal is in the acceptable range (3±12%), whilst the nitrogen contents in the weld metal is 0.13±0.15 wt% corresponding to a nitrogen content in the argon shielding gas of 3±5%, v/v.

N. Kishore Babu, S. Ganesh Sundara Raman states that the β grains at the edge of the weld pool act as an ideal substrate upon which growth of the solid phase into the molten pool can occur. Though solidification occurred epitaxial, The average grain size values of welds in the unpulsed and pulsed conditions were342 μm and 266 μm, respectively. Current pulsing resulted in modest grain refinement. The decomposition of β grains can take place diffusion ally to the α phase or martensitic ally to the α′ phase or, more commonly, to a mixture of both. From the optical micrographs it was not possible to distinguish between the α and α′ phases. Micrographs were taken in locations predominantly in the regions of the diffusion α colonies for the pulsed weld, which shows diffusion α in the form of a colony structure separated by β at grain boundaries. The periodic variations in the arc current result in similar changes in the arc forces impinging on the weld puddle which are proportional to the square of the welding current. The enhanced fluid flow in pulsed current welding results in shallower thermal gradients and, hence, in a reduced cooling rate. The TEM micrographs of welds after PWHT showed black strips of β phase between α plates. The α plates were found to be relatively coarser after PWHT at 900 °C in both cases compared with those in the as-welded condition. This is due to the presence of α′martensite in the weld metal. The high strength of themartensite in the welds is attributed to a very high defect density and the fine size of the marten site plates. There was not significant difference between the hardness values of the welds made with or without current pulsing after the PWHT at 900 °C. The UTS value continuously creased with increasing test temperature. On the other hand, elongation increased with temperature. Also, in both pulsed and unpulsed welds the α plate width was almost the same. This could be the main reason that the weldments, both pulsed and unpulsed, exhibited almost the same strength and ductility values after PWHT at 900 °C.

The result of Analysis of mean and RMS current welding in the pulsed TIG welding process is confirmed when considered the obtained width value in the bead done with constant current. This presented a width less than those obtained with pulsed currents. A weld molten zone can be understood to be the combined result of penetration and the bead width. This result therefore indicates that the weld penetrations closely related to the mean value of the welding current, since it remained unchanged in these tests. Along the same line of reasoning, we suggest that the RMS current does constitute a suitable parameter for comparative analysis related to the width of welds inpulsed TIG welding processes. The width values, penetration, and molten area of these weld beads. It can be seen that the penetration of the weld beads decreased as the mean welding current decreased. On the other hand, the width of the weld bead obtained in these experiments remained constant.

Thus, the molten are obtained in these weld beads showed a similar behavior to those obtained in previous tests, but in this case in accordance with penetration behavior. These results corroborate with the previously obtained results discussed in the introduction of this paper. Whereas in the first stage of the work we obtained penetration values equal in welds performed with pulsed current with equal mean current values, in the second stage, lower penetration values were obtained for lower mean current values. This therefore leads to the conclusion that the RMS welding current can be used as a suitable parameter for the analysis of the width of weld beads obtained by pulsed TIG processes. In the same way, the mean current can be used as a suitable parameter for analysis of the penetration of the respective weld beads. However, when analyzing the obtained beads, it appears that the penetration of the respective beads was practically the same. Similarly, in tests 2 and 10, pulse amplitudes that resulted in currents of 110 and 200 A, respectively, were used, resulting in beads of very similar widths. Based on tests 1, 2 and 8, it was found that although the mean value of the welding current in all of these tests is substantially the same, the penetration value obtained in the test with constant current was increased.

A. Kumar, S. Sundarrajan describes that during tensile tests, all the welded specimens were failed within the weld region. Hence, ultimate tensile strength is equal to the strength of the weld. Pulsed welds have shown fine grain structure compared to the continuous welds is due to thermal disturbances and decrease in heat input. In general, hardness in the fusion zone is lowest due to the as cast nature of the microstructure, which is characterized by the coarse dendrite grains, inter dendritic segregate phases, and the lack of strengthening phase. Hardness is higher compared to the continuous welds and this could be due to refinement of grain structure and low segregation of phases [9].The portion of the HAZ close to the weld is harder than the rest of the HAZ, but still softer than the base metal [10]. It is due to the fact that, weldment was subjected to sufficient heat for a reasonable amount of solution zing (i.e. all the elements are dissolved in single solid solution) and fast enough cooling rate to be quenched and produce a somewhat super saturated solid solution. The microstructures at the weld center of pulsed welds using the experimental layout .it is evident that, the samples welded by using the condition i.e. Pm5 (peak current – 80 A, base current – 40 A, welding speed – 230 mm/min, and pulse frequency – 4 Hz) resulted in fine equated grains compared to other conditions. It is also observed that a fine interdendritic network of aluminum with much of the Mg2Al3 eutectic (dark) precipitates near grain boundaries. It is evident that at higher frequency, the thermal and mechanical disturbances might be more which is due to fact that the weld pool resonant frequency is closer to the experimental frequency of operation, i.e. at 4 Hz. Similar trends have been observed in the literature [11,12].The microstructure observation of the condition set i.e. Pm4 (peak current – 70 A, base current – 50 A, welding speed –230 mm/min, and pulse frequency – 2 Hz) is resulted in coarse grain structure. It might be expected that the thermal and mechanical disturbances would be less at lower frequencies. From the observation of the weld microstructures, it is clear that, the combination of peak current, base current, welding speed and pulse frequency resulted in fine equated grain structure. Mathematical models have been developed and written in MATLAB. The developed programs have been used to estimate the mechanical properties of AA 5456 Aluminum welds. Predicted values are plotted as graphs and presented. The plotted graphs can be effectively used to understand the effect of peak current, base current, pulse frequency on mechanical properties of AA5456 Aluminum alloy welds.

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