The effect of welding parameters on surface quality of AA6351 aluminium alloy

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Abstract. In the present work, the effects of gas metal arc welding-cold metal transfer (GMAW-CMT) parameters on surface roughness are experimentally assessed. The purpose of this study is to develop a better understanding of the effects of welding speed, material thickness and contact tip to work distance on the surface roughness. Experiments are conducted using single pass gas metal arc welding-cold metal transfer (GMAW-CMT) welding technique to join the material. The material used in this experiment was AA6351 aluminum alloy with the thickness of 5mm and 6mm. A Mahr Marsuft XR 20 machine was used to measure the average roughness (Ra) of AA6351 joints. The main and interaction effect analysis was carried out to identify process parameters that affect the surface roughness. The results show that all the input process parameters affect the surface roughness of AA6351 joints. Additionally, the average roughness (Ra) results also show a decreasing trend with increased of welding speed. It is proven that gas metal arc welding-cold metal transfer (GMAW-CMT) welding process has been successful in term of providing weld joint of good surface quality for AA6351 based on the low value surface roughness condition obtained in this setup. The outcome of this experimental shall be valuable for future fabrication process in order to obtained high good quality weld.

1. Introduction

The quality of the joints depends on the processing parameters. Surface finish is very crucial characteristic to be considered in assessing the performance of fabrication process. The main objective of modern industries is to manufacture low cost, high quality products in short time [1]. Many authors [2-4] have agreed that the welding parameters can affect the weld bead characteristics. It is proved that it is vital to know how the welding parameters responses affect the surface roughness.

Welding is one of the most important and versatile means of fabrication available to industry [5]. Gas metal arc welding cold metal transfer (GMAW-CMT) process is part of the fusion welding and it has been increasingly appreciated in automotive industry. The demand to improve process performance in automotive had led to the innovation of conventional arc welding method to develop GMAW-CMT welding technique. The usage of GMAW-CMT method exhibits advantages as it generate high productivity, high deposition rate, low heat input, low cost and controllable spatter.
Most of researchers were satisfied with the performance of GMAW-CMT. Cold metal transfer welding of aluminum alloy to zinc coated steel[6], titanium to copper [7], cladding of nickel base inconel 718 [8], aluminum to galvanized mild steel [9], magnesium to aluminum [10] and aluminum to aluminum [11].

Many specific properties of aluminum alloys including light weight and good structural strength enable them to be applied for structural parts. The demand of aircraft and automotive industries for lightweight materials is met by aluminum alloys [12]. Aluminum 6351 was chosen as the main material, because of its good mechanical properties and widespread usage including automation industry, structural work and shipbuilding [13]. There is no single work concern on the surface roughness of AA6351 using GMAW-CMT method. Therefore, this study is aimed at determining the effect of welding speed, material thickness and contact tip to work distance on the surface roughness of AA6351 joints.

2. Experimental set up

The AA6351 material is supplied by NovaScientific Resource (M) Sdn.Bhd. The aluminum alloy 6351 was in plate shape having two dimensions of the raw material in this sample preparation which is 150mmx 53mmx 5 mm and 150mmx 53 mm x 6mm as presented in figure 1. The plates of AA6351 were prepared using plasma cutting machine by supplier. AA6351 consists of aluminum, iron, magnesium, manganese, zinc, titanium, silicon and copper. Experiments were conducted using a GMAW-CMT welding machine as presented in figure 2. ER4043 with a diameter of 1.2mm was used as filler metal. The GMAW-CMT process was carried using single pass layer, fixture application and forehand technique. An argon shielding gas with a flow rate of 15L/min was used in the welding process. The welding parameters used during the GMAW-CMT process as shown in Table 1. Three input parameters with two levels were selected and full factorial technique was utilized to drive the experimental planning process. Totally 16 conditions with different welding speed, material thickness and contact tip to work distance have been shown in table 2. After welding process, a Mahr Marsuft XR 20 machine was used to evaluate the surface roughness of the GMAW-CMT weld by measuring average roughness (Ra). A Mahr Marsuft XR 20 surface roughness machines is a direct measurement method with static workstation. The surface roughness measurement was performed on the centre of weld zone area. The cut-off length was fixed at 0.8mm and the evaluation length measured was 4mm with sampling length 5. The measuring speed 0.1 mm/s was setup in the experiment for all measurements. All measurements were run in a surface laboratory room at UNIKL MITEC Pasir Gudang, Johor with temperature 25°C.

![Figure 1. Raw material AA6351.](image)
3. Results and discussion

The surface roughness performance in this work was observed based on the quality characteristic is the smaller the better. The collected data were analyzed using design of experiment analysis in MINITAB 16 software with average roughness as dependent variable and welding speed, contact tip to work distance and material thickness as independent variables. The results of surface roughness are shown in table 2. As experiment conducted had proved, GMAW-CMT welding process for AA6351 was observed show more great average roughness, Ra values. Information obtained from the experiments designated that none of the welding condition produced the same value of surface roughness. It also showed major differences between largest value of surface roughness and the smallest value of surface roughness. However, all trials successfully attained average roughness, Ra below than seven (Ra< 6). This means that they are categorized as smooth weld bead surface. The main effect response graph of weld bead surface roughness is shown in figure 3. The average roughness, Ra value shows a decreasing trend with increased of welding speeds. Welding speed has greatest effect on weld bead surface roughness of AA6351. So, it can be stated that lowest surface roughness can be achieved when an increase in welding speed and material thickness. This finding meets an agreement with the theoretical information stated that increased welding speed does not result rough bead. Figure 4 shows the outline for interaction plot of GMAW-CMT welding parameters on the surface roughness. It was observed no interaction effects between welding speed and contact tip to work distance.

Table 1. Welding process parameters and their levels.

| Process parameters          | Levels |     |
|----------------------------|--------|-----|
| Material thickness (mm)     | Level 1 | 5   |
| Welding speed (mm/min)      |         | 500 |
| Contact tip to work distance(mm) | Level 2 | 6   |
|                            |        | 10  |
|                            |        | 15  |
Table 2. Results of surface roughness.

| Trial | Average roughness, Ra (µm) |
|-------|---------------------------|
| 1     | 5.0569                    |
| 2     | 3.9546                    |
| 3     | 3.4118                    |
| 4     | 1.971                     |
| 5     | 2.2029                    |
| 6     | 5.9394                    |
| 7     | 3.7081                    |
| 8     | 3.2535                    |
| 9     | 2.1689                    |
| 10    | 3.0413                    |
| 11    | 4.085                     |
| 12    | 2.5745                    |
| 13    | 5.3105                    |
| 14    | 4.7378                    |
| 15    | 2.5095                    |
| 16    | 2.5046                    |

Figure 3. GMAW-CMT welding machine
Conclusion

It can be concluded that increasing welding speed and material thickness decreased the surface roughness whereas increasing the contact tip to work increased the surface roughness. The welding speed, contact tip to work distance and material thickness has significant effect on the surface roughness of AA6351 welded joints. In additional, it can be stated that lowest surface roughness can be achieved when an increase in welding speed and material thickness which material thickness substitute to welding current and welding voltage.

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