Correlation between Micro hardness and Microstructure of CMT Welded AA 7075 Al Alloy

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Abstract. The Cold Metal transfer process have recently gained significant importance in the manufacturing sectors due to its excellent droplet transfer of consumable in the molten pool with no spatter. The 7xxx series of Al alloys are the most preferable material to dynamic applications. Hence, in this research work, the AA7075 Al alloys were joined using an advanced TPS 400i Cold Metal Transfer (TCMT) welding machine in order to understand the homogeneity of the weldment with respect to its microhardness and the correlation between the microhardness and microstructure of the joints were analyzed. Finally, it was found that the hardness was decreased in the Weld Zone (WZ) compared to Heat Affected Zone (HAZ) and the Base Metal (BM) and also the metallurgical characterization reveals that the joint is free of defects and fine grains were observed in the WZ.

1. Introduction

The current, demands reduction in vehicle emissions to meet stringent pollution norms. Among several approaches like hybrid vehicle and electric vehicle, the prominent is using lightweight vehicles without compromising on safety. To develop light weight vehicles, manufacturers rely on dissimilar combinations of alloys like aluminium, magnesium and advanced high strength steels where the aluminum alloys were the prime choice for the fabricators due to its availability and also economically. There are variety of welding approaches for joining Al alloys but most of them result in severe defects in its own form. All of the solid state and fusion state welding techniques were ideal under certain conditions. This made the research society to develop a new technology to exhibit better properties in dynamic conditions compared to the existing processes [1-3]. Finally, in 2004, **FRONIUS** came up with an idea of joining the aluminum alloys with a renowned MIG welding process known as Cold Metal Transfer (CMT) welding process which has the same basic principle as that of conventionally used MIG except the fact it uses a

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droplet transfer mechanism to the electrode tip whose actions are controlled by a servomotor during the process [4].

A novel joining route for Aluminum alloys using CMT welding process was explained by **Pickin** et al [5] in which the mechanical properties of the joints were found to be better compared to the conventionally used MIG/MAG process. The control of mass and heat during cold metal transfer process was initially found to be very difficult which was substantiated by **Mezrag** [6] by means of reducing the heat transfer modes during the process which contributes for the homogeneity in the weld zone. The investigation of droplet transfer behaviors in cold metal transfer process on welding Ti-6Al-4V alloy was performed by **Zhe Sun** [7] and the innovative use of low heat input in CMT welding process was explained by **Lorenzin** [8] from which the droplet transfer modes and the subsequent solidification were well understood. The dissimilar joining of steel to aluminum was carried by **Shang** [9] et al to identify the feasible working limits for joining the dissimilar materials and also to find the weldability of steel to aluminum alloys. Though there are many recent developments in the CMT process for joining variety of materials yet there is no sufficient technical reports regarding the mechanical properties and the microstructural variations of the joints. Hence, in this research work, an advanced TPS 400i CMT (TCMT) welding process have been utilized for joining the aluminum alloy and the corresponding mechanical, microstructural properties were identified using advanced facilities and their properties were correlated to understand the droplet transfer mode during the advanced CMT process.

2. Experimental work

The AA 7075 Aluminum alloy (5mm thick) were used in this research work due to its wider applications and availability. The **Zn** (5.83%) and **Mg** (2.3%) were found to be the major alloying elements in this aluminum alloy along with **Cr** (0.072), **Cu** (1.54) and **Fe** (0.57) which was identified using a vacuum spectrometer. The mechanical properties of the base Al alloy are displayed in Table 1. The metal was then joined using an advanced CMT welding machine (TPS 400i) wherein the heat input was controlled while the electrode tip makes contact with the molten pool by a droplet mechanism. This short circuit transfer creates no spatter during welding and also the wave cruciform will be synchronous and uniform throughout the process. The figure 1 (a-b) shows the Advanced CMT welding machine and the corresponding joints were fabricated under the welding conditions of current 90A, voltage 12.5 V and welding speed 275 mm/min.

Table1. Mechanical properties of the Base Al alloy

Yield Strength (MPa)	Tensile Strength (MPa)	Fatigue Strength (MPa)	Hardness (Hv)	Elongation (%)
508	542	173	160	12

The welded joints were drawn using a wire cut EDM and the microhardness and microstructural specimens were prepared as per ASTM specifications. The hardness of the joints were evaluated using a Vicker's microhardness tester wherein the hardness values were displayed digitally and the results were recorded. The optical microscope was used to visualize the grain orientation at different zones in the joints and the corresponding grain formation were observed to understand the nature of the joints.

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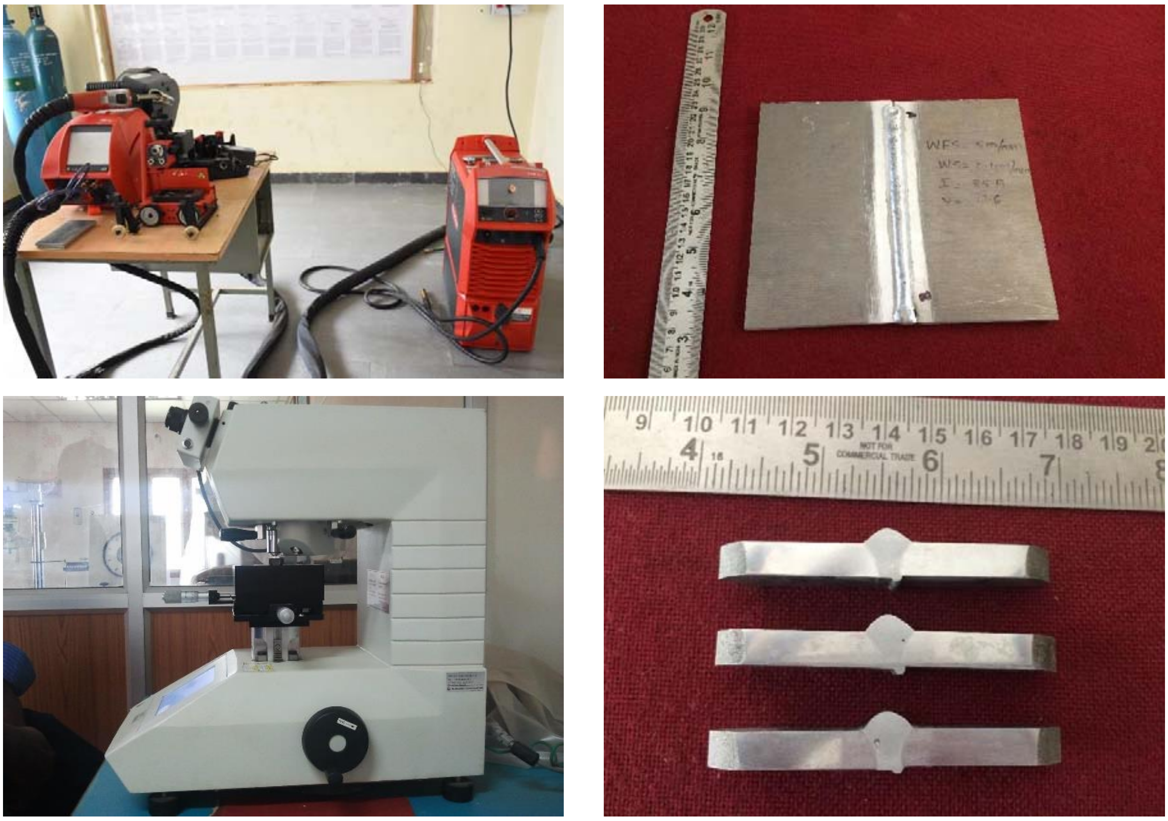

Figure 1. The Experimental work (a) CMT welding machine, (b) CMT joints, (c) Vicker's microhardness testing machine, (d) Microhardness specimen

3. Results and Discussion

The microhardness variation across the weldments were recorded and the average of the results were taken. It was found that the hardness was decreased in the Weld Zone (WZ) compared to the Heat Affected Zone (HAZ) and the Base Metal (BM) which is achieved due to the short circuit transfer between the electrode tip and the molten pool. The average microhardness across the weld zone was found to be 123.2 Hv and on the other hand, the HAZ shows an average microhardness value of 136 Hv which is an increase of 10.38 % compared to the WZ which was found to be better than the conventional fusion welding techniques which was also highlighted by Elrefaey [10].

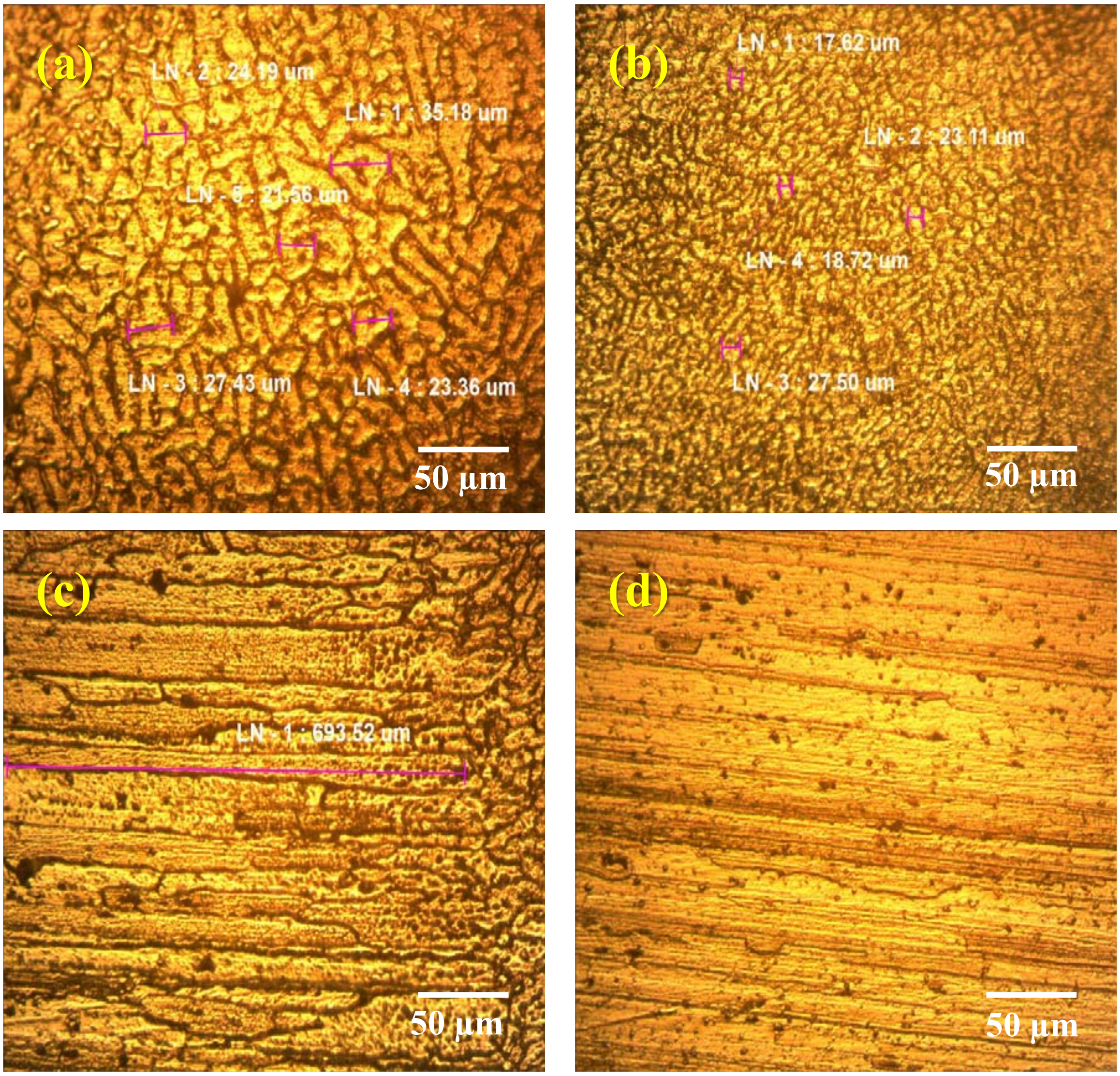

Figure 2. The Microstructural Results (a) Micrograph of WZ at 400 X, (b) Micrograph of the WZ at 200X, (c) Micrograph of the HAZ at 200X, (d) Micrograph of the BM at 200X

The microstructure of the joints analyzed by optical microscope shows no defects throughout the weldment and also the grains were uniformly distributed with only minute pores been observed. The figure 2 (a-d) depicts the microstructural results of the various zones of the CMT welded joints. The fine grains were attained in the weld zone with no solidification defects and the HAZ was found to be very narrow which is possible due to the controlled heat input during the welding process and rapid solidification of the molten pool [11-12].

Also a relationship between microhardness and microstructure has been established to understand the effect of microhardness attributing to the grain size. Hence, the hardness of various zones and the corresponding grain size of the joints acquired from the experimentations were related and expressed in figure 3. Using a straight line, the experimental data points were fitted which was governed by the corresponding regression equation:

$$\text{Hardness} = --1.1017\ (\text{Grain size}) + 169.97\ \text{Hv} \quad (1)$$

From the above regression equation, the slope (−1.1017) is found to be negative, which indicates that if the grain size increases, the hardness of fully deformed zone decreases. From the Fig. 3, it can be inferred that the hardness is inversely proportional to the grain size of the CMT welded AA7075 aluminum alloy joints.

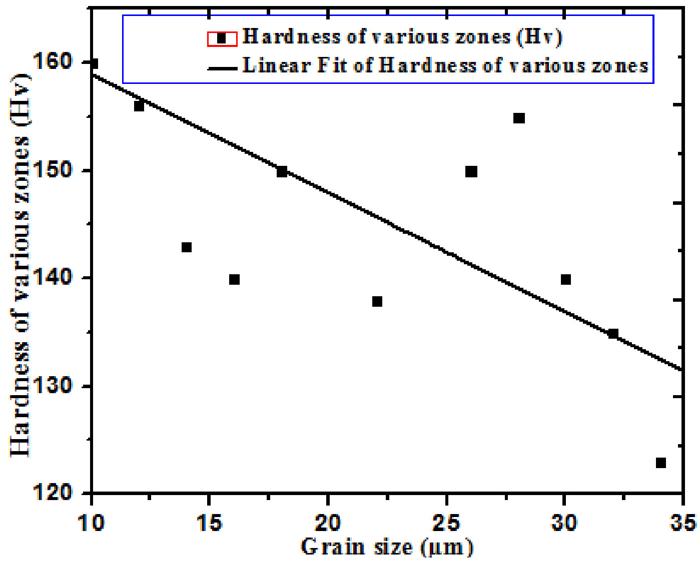

Figure 3. The relation between hardness of various zones and grain size

Therefore, from the mechanical properties and the microstructural characteristics attained it can be concluded that the weldment doesn't undergo any phase transition because of the innovative metal transfer (hot-cold-hot) in this process which provides a limited heat input across the weld zone due to the retraction of the wire which provide better weld aesthetics.

4. Conclusion

- The AA7075 Al alloy were successfully joined using advanced TPS 400i CMT welding machine
- The microhardness of the joint was found to be 123.2 Hv across the weld zone and the heat affected zone shows a microhardness of 136 Hv which is an increase of 10.8 % compared to the weld zone
- The grains were homogenous and very fine grains were observed in the weld zone with no solidification defects
- The microhardness exhibits inversely proportional relationship with the grain size of various zones
- The rapid heating and rapid cooling in the process facilitates an enhanced mechanical and metallurgical properties of the joints

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