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Improve the Mechanical Properties of Ti-6Al-4V Component Fabricated By Additive Manufacturing UsingGas Tungsten Arc Welding Technique.

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Abstract- *Recently, dynamics of markets and technological advances have brought changes in metal processing. Wire and Arc Additive Manufacturing (WAAM) is an innovative manufacturing process, that offers near–net shape fabrication of expensive material and complex components to produce large custom- made metal parts with high deposition rates. This technology has been mainly utilized in aerospace, automotive and biomedical industries, particularly withinTi-6Al-4Valloy in order to reduce the material waste, and cost of any substantial machining that required in conventional processes. Four tensile samples were taken from Ti-6AL-4V alloy which was fabricated by AM technique, these samples were prepared two of them in a horizontal direction and two in a vertical direction. The results showed that the tensile strength for the samples in a horizontal direction are higher than the tensile strength for samples in a vertical direction, whereas the ultimate tensile strength (UTS)in a vertical direction become higher than in a horizontal direction after the heat treatments. in addition the overall percentage of strain for samples before heat treatments in a horizontal direction are higher than that in a vertical direction. Micro hardness data show that there are no significant changes in micro- hardness(Vickers Hardness)measurements for all samples except heat treated sample at 1040 ^{0}C for two hours and quenched sample at 900^{0}C, their results show slight increase in the hardness. The data also shown that there are no differences in hardness observed between the top region and the bottom region of each sample.*

Keywords:*Ti-6AL-4V alloy ,Tungsten arc Welding Technique, Mechanical Properties. Micro hardness.*

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I. INTRODUCTION.

Additive manufacturing (AM) is defined as a new near net shape fabrication technology used to produce solid components by consolidating partially or fully melted layers of powder or wires [1,2]. Ti- alloys, in particularTi-6Al-4V alloy has a high strength combined with allow density (4.5 g/cm^3), good creep resistance up to 550^{0}Cand excellent corrosion resistance [3, 4]. Those attractive properties make Ti- 6Al-4V alloy an excellent choice for aircraft components such as air frames, aero- engines as well as bio-medical devices. However, the main drawbacks of production Ti-6 Al-4V by conventional routes are: these processes are energy intensive as well as a large amount of material will be wasted [4]. In order to decrease the overall cost of production, significant research has been focused on alternative manufacturing processes [4]. Additive manufacturing techniques have seen a rapid emergence recently [5, 6]. AM techniques have increased material utilization and enhanced design flexibility by deposition and bonding of successive layers of material in three dimensional. Therefore, the waste and the cost of materials have been significantly decreased by using AM techniques. The wire arc additive manufacturing (WAAM) process, which considered as one of AM techniques has been proved to be an efficient manufacturing process for Ti- alloys components [7]. With the rapid deposition of Ti-6Al-4V alloy and buy-to-fly ratio is near to one. Furthermore, the low cost and flexibility of WAAM process, especially, with complex geometries Figure -1,so it offers to designers the opportunity to create complex components, which previously was considered impossible to build. Therefore, a large expected market of WAAM technology due to its superiority on Ti alloys industry. A few research's was conducted to characterize aspects of Ti-6Al- 4Vcomponents manufactured by WAAM technology. The aim of this study is to improve the mechanical properties(tensile strength, yield strength, total elongation and hardness of Ti-6AL-4V alloy fabricated by tungsten arc welding technique.

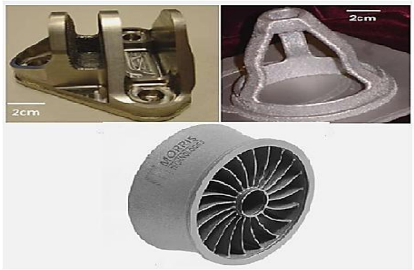

Figure 1: Examples of Additive Manufacturing Ti-6Al-4VComponents produced for race industry and aerospace industry[8,9].

II. MATERIALS AND METHODS

Ti-6Al-4V alloy used in this study is a small sample as shown in Figure-2 manufactured by WAAM process based on TIG technique. The chemical composition of Ti-6Al-4V alloy as showed in Table-1.

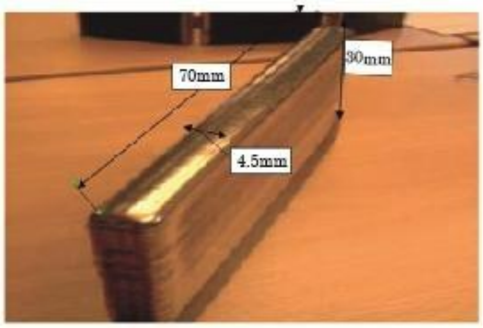

Figure 2: Shows Ti-6AL-4V alloy Sample used.

Table 1:IllustratesChemical Composition of Ti-6Al-4V alloy used.

Element	**Ti**	**Al**	**V**	**Fe**	**O**	**C**	**N**	**H**	**Y**
Chemical Composition%	89.5	6.08	4	0.18	0.16	0.035	0.011	0.0017	0.001

This sample was cut to smaller pieces in order to cover whole study needs of tensile test samples and micro-hardness samples.

III. RESULTS AND DISCUSSIONS.

1. Tensile Test Results

In this part of research, the attempt carried out to analyze the tensile testing results in vertical,(build direction)and horizontal direction of as received samples. The results of annealed tensile samples at 1040^0C and 900^0C respectively, will be discussed in order to understand the effect of annealing treatments on the ultimate tensile strength and the ductility in vertical and horizontal directions the results obtained as shown in Figures (3-6) below.

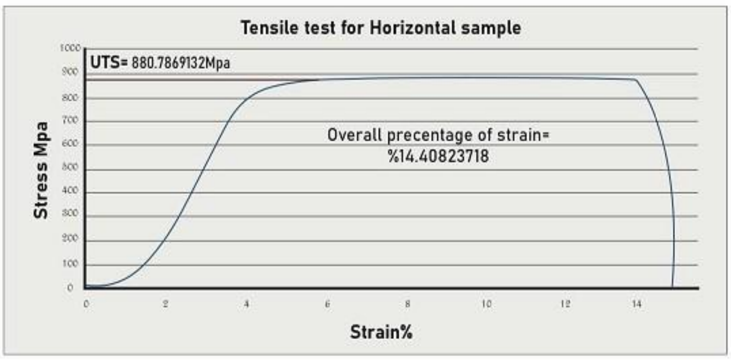

Figure 3: Shows the Tensile test results as received sample in Horizontal direction.

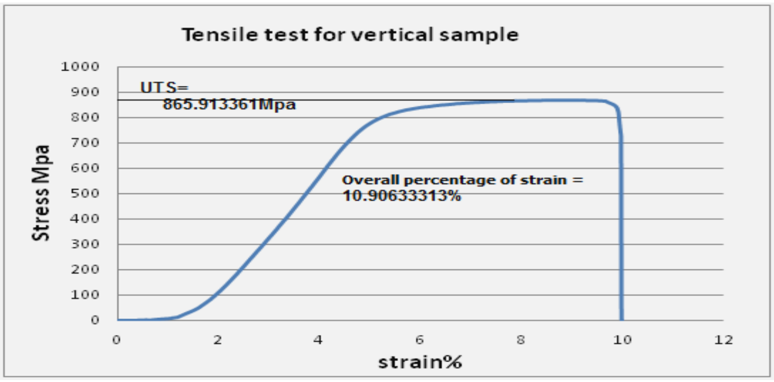

Figure 4: Shows the Tensile test results as received sample in Vertical direction.

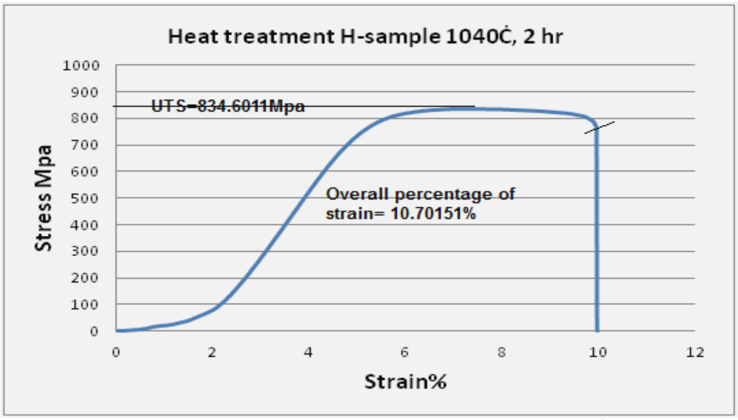

Figure 5: Shows the Tensile test results of annealed sample at 1040 ^{0}C in Horizontal direction.

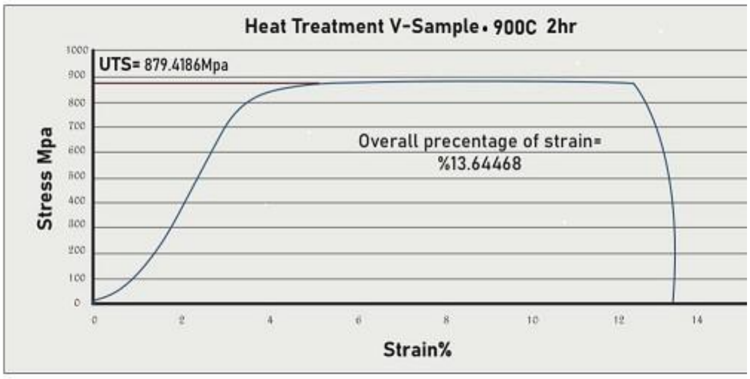

Figure 6: Shows the Tensile test results of annealed sample at 900 ^{0}C in Vertical direction.

From the above summarized tests results that shown in the Figures (3-6) it can be concluded that the tensile test results for as received samples which illustrated in last figures, the tensile test results obtained for horizontal sample are: (UTS= 880.8MPawith overall percentage ofstrain14.4%. However, these results in horizontal direction are higher than the tensile results in the vertical direction, which was: (865.9MPa) with overall percentage of strain is 10.9%. This is meant that UTS and the overall percentage of strain in horizontal direction are higher than that in vertical direction by 0.12%,24.4% respectively. The heat treatment of tensile samples was changed these results. The ultimate tensile strength and the overall percentage of strain of the horizontal annealed sample at 1040^{0}Cfor 2hours are decreased to be (834.6MPa,10.7%) respectively, while in the vertical annealed sample at 900^0 for 2hours are largely increased to be(879.4MPa,13.64%)respectively. These results can be interpreted due to the different grains growth in both treatments and their effect on the slip-length. So, when the horizontal annealed sample was heated at 1040^{0}C, the massive grain growth will be produced and this will lead to increase the dislocation slip length, which results in decrease the UTS of the sample. Whereas, annealing of the vertical sample at 900^{0}C results in making the microstructure to be much finer and homogeneous, therefore, the UTS for this sample is significantly improved.

2. Micro Hardness Test Results

Micro hardness Vickers was measured by using micro hardness machine using load of 100g, heat treated and untreated samples were evaluated from top edge to bottom edge the results obtained as shown in Figures (7-10) below.

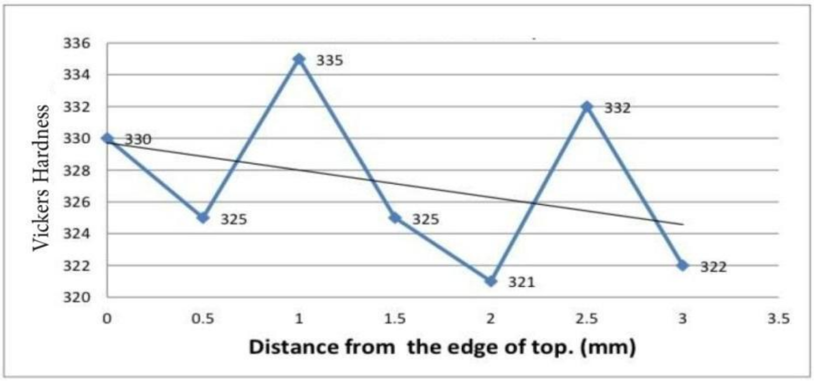

Figure7: Shows Results of Micro hardness analysis for XZ-as received sample.

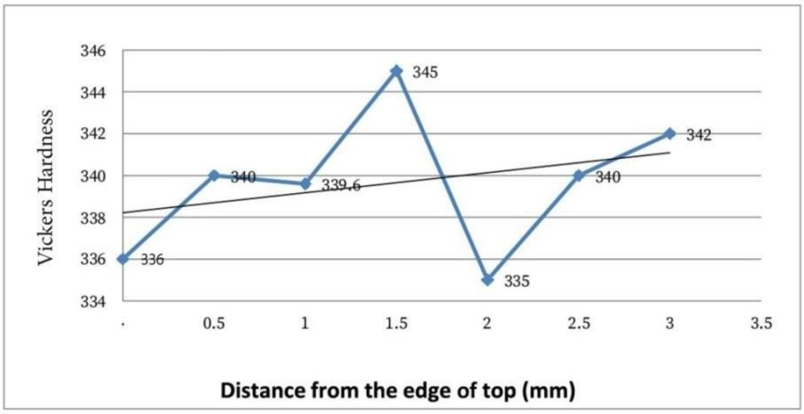

Figure 8: Shows Results of Micro hardness analysis for annealed sample at 1040^0 C.

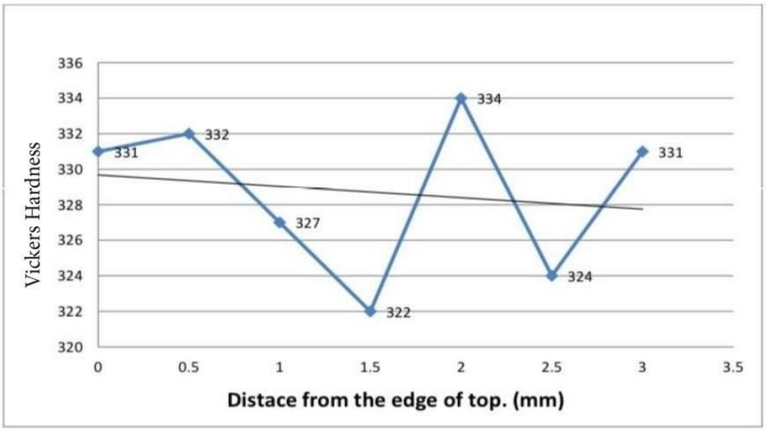

Figure 9: Shows Results of Micro hardness analysis for normalized sample at 900^0 C.

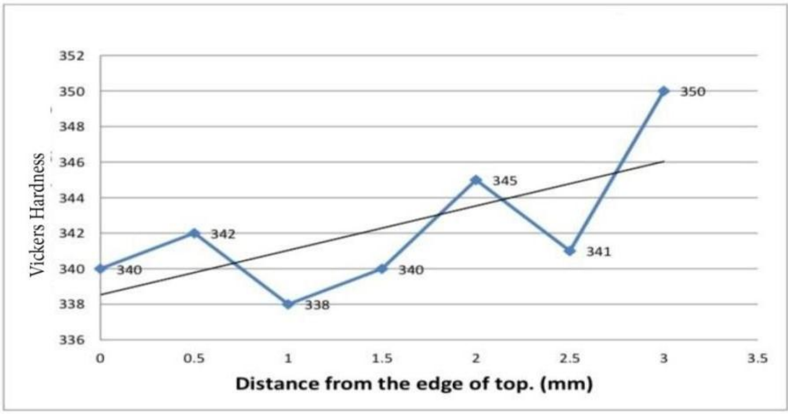

Figure 10 : Shows Results of Micro hardness analysis for quenched sample at 900 ^{0}C.

From the above summarized results that shown in the Figures (7-10) it can be concluded that the Vickers micro hardness data show that there are no significant changes in measurements for all samples except heat treated sample at 1040^{0}C for 2hours and quenched sample, their results show slight increase in the hardness. The data also shown that there are no differences in hardness observed between the top region and the bottom region of each sample. The average hardness for whole specimens is a very narrow, between 327-342 VH. The slight higher hardness in annealed sample at1040^{0}Cfor two hours. withaveragehardnessis340VHas illustrated in Figure.8 may be produced due to the large increase in the size of grains, which results in increase the slip length. The slight increase in the hardness of quenched sample as indicated in Figure.10 may interpret due to the formation of fine mixture of widmanstatten structures and some martensitic phases that contribute to increase the hardness of the sample.

IV. CONCLUSIONS.

The following conclusions have been drawn from this study:

1. WAAM process using GTAW technique produces near net shape Ti- 6Al-4Vcomponents with mechanical properties competitive to other additive layer manufacturing process as well as conventional process.
2. The ultimate tensile strength of as fabricated sample meets the specification limit of wrought Ti-6Al-4Valloy, with higher value in horizontal direction than in vertical direction.
3. The overall percentage of strain for samples in a horizontal direction are higher than that in a vertical direction.
4. The results of tensile samples have changed after the heat treatments. The ultimate tensile strength in avertical direction become higher than horizontal direction.

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