Effect of Rolling on Hardness of Aluminium Metal Matrix Composites - An Experimental Study

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***Abstract*: The objective of the investigation is to fabricate a composite material, which is to be used as an alloy wheels in automobile vehicles. The Metal Matrix Composite includes two metals which includes aluminum, and chromium. Aluminum is chosen because of its superior strength to weight ratio. Chromium is chosen because of its strength-weight ratio. The fabrication of composite material is done through stir casting method. Deformation of composite done using manual rolling after the casting of composite. Further analysis of composite includes microstructural study, hardness values and machinability results. The specimens are collected for every work to analysis the composite.**

***Keywords*: Machinability, Metal matrix composite, Rolling process, Stir casting.**

1. Introduction

Understanding of how materials behave like they do, and why they differ in properties was only possible with the atomistic understanding allowed by quantum mechanics that first explained atoms and then solids starting in the 1930s. The combination of physics, chemistry, and the focus on the relationship between the properties of a material and its microstructure is the domain of materials science. The development of this science allowed designing materials and provided a knowledge base for the engineering applications Materials used in "High-Tech" applications, usually designed for maximum performance, and normally expensive. Examples are titanium alloys for supersonic airplanes, magnetic alloys for computer disks, special ceramics for the heat shield of the space shuttle, etc.

A composite is a material that consists of at least two chemically and physically distinct phases suitably distributed to provide properties not obtainable with either of the individual phases. Aluminum alloys, aluminum nickel alloys, magnesium, steel, etc. has been used in recent times in aerospace and automotive industries because of their high temperature resistance and superior strength to weight ratio. The objective of the investigation is to fabricate a composite material which is to be used as an alloy wheels in automobile vehicles. The MMC includes two metals which includes aluminum, and copper. Aluminum is chosen because of its superior strength to weight ratio. Copper is chosen because of its ability to dissipate heat quickly. The fabrication of composite material is done through stir casting method. Further microstructure analysis is conducted, in order to show the dispersion of the copper with the aluminum. Cross sectional area reduction will be done using manual rolling after the casting of composite. Different tests (microscopic analysis) will be conducted on composite specimens after rolling for documentation of properties.

2. Literature Review

The particulate aluminum magnesium metal matric composites have been studied for their commercial usage and application and have made a review of their properties by studying the fabrication process. The microstructural evolution and mechanical properties of the aluminum/15 vol.% alumina composite are reported and the composite have shown the increase in the accumulative roll bonding cycles with increase 4 times when compared to annealed aluminum. Achievement of the strengthening mechanism by addition of the SiC to aluminum alloy have increased the yield stress as the function of the particulate size and there by proposing that the microstructural changes impacts the yield stress of the composite. The investigation of the rupture mode after the ARB process is the shear ductile fracture for the Multi layered Al/Cu composite achieved by the ARB process using the Al1100 and Cu strips. The processing technique for the particulate reinforcement metal of aluminum matrix composite have been made by addressing the all the possible particulate additives such as the copper, nickel and Silicon Carbide has made. Various physical properties have been computed by utilization of the Artificial neural networks with the god approximation and thereby reducing the testing time. The various effect of the volume fraction of SiC on the various physiological properties of the Al4.5Cu-3Mg matrix alloys has been studied and the increase in the volume of the particulate has increased the porosity and decreased the elongation of the composite.

3. Experiment

Commercial pure aluminum (99%) was used as the base matrix. Chromium (99.9%) was used to prepare the powder. First the Aluminum was melted in a crucible by heating it in a muffle furnace at 800ºC for three to four hours. The copper particles are preheated at 400ºC for one to three hours to make their surfaces oxidized. The furnace temperature was first raised above the melting point of aluminum (750ºC) to melt the aluminum completely and was then cooled down just below the melting point to keep the slurry in semi solid state.

Stirring was carried out with the help of stainless steel stirrer coated with fire clay. At this stage, the preheated copper particles were added manually to the vortex. In the final mixing processes the furnace temperatures was controlled around 700ºC. Melt was poured immediately after stirring into the 18 mm diameter finger moulds as shown in fig. 1.

Fig. 1. The finger mold made by the stir casting method

Standard sample: (deformations 30%,40%) Sample of Rectangular mould was prepared for iterated hot rolling to reduce the cross sectional area. A 1½ inch length pieces were taken as standard specimens of different reduced areas for further tests like microscopic analysis, hardness tests and machinability tests.

The steps that have been taken to achive the stir casting process is given as follows, heat treatment and mechanical treatment is made to allow the casting to smoothen the layers.

Heat treatment given:

- Homogenization of sample at 100ºCare soaked for 24hr and then air cooled.
- For each deformation sample is made to introduce at 450ºC into the rollers.

Mechanical treatment:

Standard reduction in cross sectional areas of 30 and 40% were given to sample in iterative steps of hot rolling. Specimens were collected for every reduction in cross sectional area for further studies like microscopic analysis and hardness tests.

- Sample was introduced at 450ºC into the rollers, the cross sectional area reduced by 30% of original area and 1½ inch piece was taken as the standard specimen.
- Again the same steps were repeated for collecting standard specimens of 1½ inch reduced cross section areas up to 40%.
- These specimens will be used for microscopic analysis and hardness tests.

Fig. 2. The specimen showing the Aluminum copper metal matrix composite before rolling

Fig. 3. The rolled specimen showing the convex shape after rolling.

Casting operation:

- Composite Specimens, with deformations 30%,40% and without deformation of dimension 17mm diameter, each ½ inch length were taken for microstructure and hardness tests.
- Microstructures were taken using optical microscope.
- Hardness value of specimen was measured using vicker's hardness test.

Fig. 4. The Vickers hardness-testing machine which is used for testing the hardness of the derived samples

The Vickers hardness test method, also referred to as a micro hardness test method, is mostly used for small parts, thin sections, or case depth work. The Vickers method based on an optical measurement system. The micro hardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from a few grams to one or several kilograms. The micro hardness methods are used to test on metals, ceramics, and composites almost any type of material.

The adaption of Universal hardness testing machine is used of model UH-3 with the load range of 1-500 kg and it is carefully made to follow the ASTM E384 standards very strictly.

4. Result

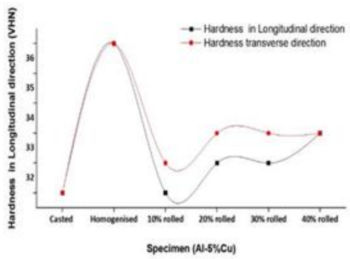

Fig. 5. The graph shown the experimental results of hardness values of the aluminum copper metal matrix composite in different directions

From the above graph it is observed that the as the specimen is been changed there is increase in the hardness for the homogenized composite for the both the direction, but the offset trend with the increasing in the hardness has been found for the different directions. Though the 40 % reduction have achieved the same results for both the directional hardness measures. Hardness of the composite can be raised from homogenization process because of stabilized properties. The Hardness value of 10% deformed specimen is less compared to homogenized casted specimen because of sudden change in grain size and grain locations, which cause the instability of properties. There is no much difference in hardness due to deformation because of iterative steps of heating where hardness gained by one deformation will be lost because of exposing to high temperatures to perform the next deformation. It has been observed that the Hardness is always more in transverse direction compared to longitudinal direction.

5. Conclusion

In this experiment, homogenization is directly proportional to hardness but it may contradict based on homogenization temperature and time span. Micro hardness suddenly drops from homogenized specimen to 10% deformed specimen because of exposure of specimen to high temperatures before deforming the specimen, which might have affected the specimen properties. Deformation have impact on micro hardness but it is randomly increased achieving the offset trend varied. Material removal rate results are bit far away from expected. These results may be effected by so many factors like small depth of cut, environmental factors, Non- conventional machining study, grain variations, particle distribution etc.

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