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Effect of Mg, SiC and Fly Ash Particulates in Aluminium Alloy for Automotive Wheel Rim Applications

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ABSTRACT:

For the past few decades the wheels of an automobile are usually made out of alloy materials. Due to the increased demand for peculiarity and enhanced outlook, metal matrix composites can be used for the alloy wheels. They enhance the performance of the vehicle by reducing its weight and thereby increasing its fuel efficiency. Many literature works are initiated and progressed on design and development of automotive alloy wheels. There is a scope for enhancing their properties with reinforcements. This study focuses on manufacturing a novel metal matrix composite material comprising aluminium as metal matrix and magnesium, silicon carbide and fly ash as reinforcements. The newly fabricated composition is tested. The alloy wheel is further analysed using ANSYS. The analysis results are compared with that of the existing aluminium alloy. The obtained results confirm that the proposed metal matrix composite is a reliable replacement for the aluminium alloy.

KEYWORDS:

Alloy wheels; Aluminium metal matrix composite; Finite element analysis; Mechanical testing

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1. Introduction

Metal matrix composites (MMC) can be defined as a composite material which comprise a metal as a matrix and other material which can be ceramic material or an organic compound as reinforcement. MMCs when compared with conventional materials are usually expensive. The new compositions are designed and their properties are improved. For high end applications like aircraft components, high quality sport equipment and in space systems these composite materials are used and there has been a wide increase in their usage. Due to this increased usage, the manufacturing cost also has been reduced. Ganesh et al [1] studied Aluminium alloy wheel for a four-wheel vehicle and concluded that magnesium rims are strong but they are not suitable for off road SUV vehicles. Further, there are not repairable if it is bent yet these were used in Mercedes-G car models. After doing the researches on various materials for wheel rims, Kale et al [2] concluded that if the requirement is to obtain aesthetics shape with excellent design having a better heat dissipation without compromising on the cost associated then alloys of Al and Mg can be used [3-4].

Jian et al [3] discussed about Mg alloy wheel upon the factors that influence their forging forming force. As the temperature of die and material reduces the forging forming force increases and there is a considerable increase in friction coefficient. Dede et al [5] focused on stress and displacements that are caused in an automobile rim and concluded that smoother outer surface of wheel has resulted in further reduction in air resistance. Igbudu et al [6] modelled an automobile Al alloy wheel and carried out a comparison of the loading function to the static radial load. Prasad et al [7]carried out a comparative study of aluminium and forged Steel for static displacement, Von Mises stresses and dynamic displacement and concluded that forged steel was the best material for the wheel rim comparatively. Aluminium-Magnesium 5000 series alloys have best properties and are economically best [8]. In this work, manufacturing and analysis of a novel composite material comprising aluminium as metal matrix and magnesium (Mg), silicon carbide (SiC) and fly ash as reinforcements are presented in view of possible replacement of existing aluminium alloy wheels.

2. Specimens preparation & experiments

For the aluminium metal matrix composite, the mixing ratio of Al, Mg, SiC and fly ash is as follows Al 80%, Mg 5%, SiC 10% and fly ash 5%. The proposed composition of metal matrix composites is fabricated into three different cross-sections as shown in Fig. 1. The experimental procedure comprises tensile test, Rockwell hardness test, impact test and the natural frequency testing of the material to analyse the various strengths of material and to understand the machinability of the material. The mechanical tests are carried out for the corresponding specimens to determine the properties of the proposed composition. Detailed test results are presented elsewhere.

Fig. 1: Fabricated test specimens

3. Results and discussion

Using Solidworks software a standard automobile wheel rim is modelled. The properties of the new material composition as obtained from the test data is used for the modelling and simulation. The designed CAD data is saved in IGES format and then is imported into ANSYS workbench for simulation. Fixed boundary conditions at the rim centre are applied. The output control settings are changed to stress and strain followed by updating the given inputs to solve the conditions. The stress analysis of the proposed material composition is carried out (Fig. 2). The results conclude that the new composition (Al 80%, Mg 5%, SiC 10% and fly ash 5%) showed less stress when compared with that of the existing material. Fig. 3 shows the deformation results for the new composition of MMC.

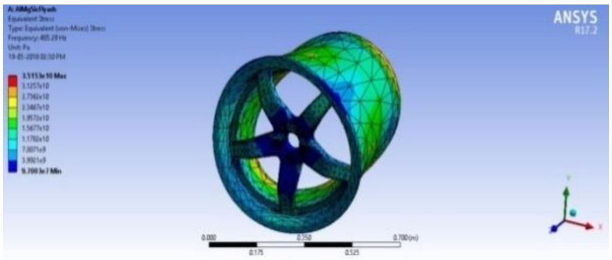

Fig. 2: Stress analysis

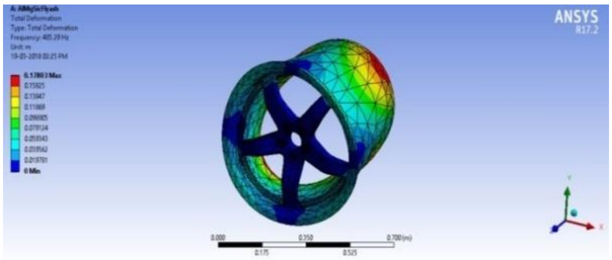

Fig. 3: Deformation analysis

The tensile test results of aluminium and magnesium are compared (Fig. 4) with that of the proposed MMC material. The proposed material has relatively more tensile strength, 131.52 MPa. Mixture of aluminium and magnesium alloys was found to be the reason for the increase in the tensile strength of the MMC compared to the aluminium alloy. The hardness of the three alloys is tested and the proposed composition of MMC was successful in exceeding the hardness of other materials (Fig. 5). This was achieved due to the reinforcements made to it namely SiC, Mg and fly ash. The proposed MMC showed a hardness value of 72 HRB. Previous studies undertaken on the mixture of Al and SiC produced positive results in the improvement of the impact strength. This is the main reason to include SiC as reinforcement in the proposed composition. The comparison of the three compositions showed that the proposed MMC composition showed a very high value of impact strength of 11 J (Fig. 6). This is because of the 10% of SiC added by weight to the MMC. Also the addition of fly ash improved the bonding property of the MMC and reduced porosity in the MMC.

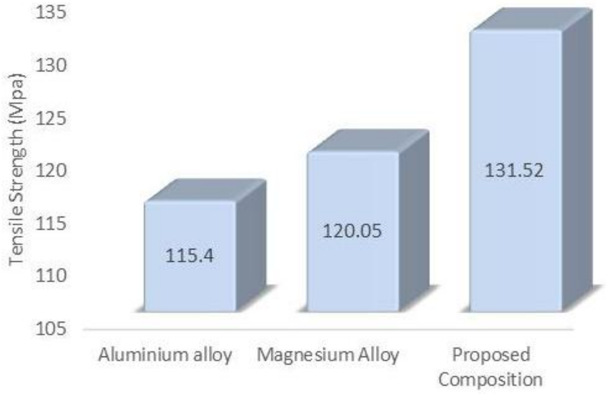

Fig. 4: Comparison of tensile strength between Al alloys, Mg alloy and proposed composition

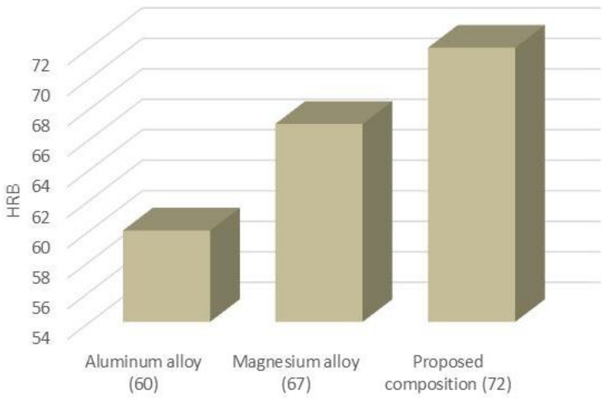

Fig. 5: Comparison of hardness for Al alloy, Mg alloy and proposed composition

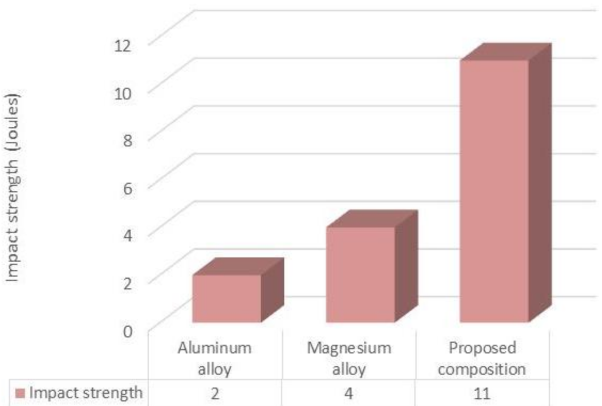

Fig. 6: Comparison of impact strength between Al alloy, Mg alloy & proposed composition

4. Conclusions

In this study a new composition of MMC specimens were fabricated by adding Mg , SiC and fly ash as reinforcements to increase its mechanical properties. The developed MMC specimens were characterized by mechanical testing in terms of tensile, impact and hardness strengths. The three tests reveal that the composite with Mg 5 % SiC 10% and fly ash 5% showed a tensile strength of 131.52 MPa, hardness value of 72 HRB and impact strength of 11 J. All these values are better than the base alloys. This implies that the new composition is a reliable replacement for the existing aluminium 6061 series alloy used for alloy wheels.

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