Optimization of Mechanical Behavior of Hybrid Aa7050 Metal Matrix Composites Reinforced With Zrb_2/Al_2o_3 for Aircraft Wing

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Abstract -In the present aerospace industries, composite materials play a significant role with their superior properties over metals and monolithic materials. The automobile and aerospace industries are currently facing significant issues in designing new products with less weight and have a high strength-to-weight ratio, thereby reducing fuel consumption and environmental emissions as accomplished by lightweight metal matrix composites. Therefore, in this work, AA7050-T7451 aluminium alloy is chosen as matrix material due to its wide application in the aerospace industry, especially in the aircraft wing spar application. To satisfy the above objectives AA7050 was selected as matrix material and it was reinforced with 1%, 2%, 3%, 4% and 5% Al2O3 and 0.5%, 1% and 1.5% of MWCNT using vibro compocasting method. In order to identify the physical, chemical, mechanical and wear properties of the developed hybrid composites. The various tests were carried out on the prepared samples based on the ASTM standards. The developed RSM model has good agreement with 99% confidence level and validated using ANOVA results.

Key word: Aluminium alloy, Composite materials, RSM, ANOVA

I. INTRODUCTION

The concept of composite material is well demonstrated from the naturally occurring composite materials such as wood in a matrix of organic polymer lignin that is usually made of fibrous chains of cellulose molecules. Bones made of inorganic composites are another example of natural composites. This section addresses the introduction of composites, classification of composites, Metal Matrix Composites (MMCs), classification of MMCs, Aluminium Metal Matrix Composites (AMMCs), Hybrid composites, Hybrid AMMCs, the fabrication method of MMcs, mechanical properties if AMMCs, tribological properties, Response Surface Methodology (RSM), aircraft wing spar application of MMCs and also illustrates the significance of Aluminium Alloy 7050 with reinforcements like Al2O3, ZrB2 and MWCNTs. Aluminium metal matrix composites and their application are also discussed in this chapter. The mechanical properties, various fabrication techniques, introduction of tribology and their properties are also described in detail. Therefore, in this chapter, the mechanical properties, fabrication methods and various application of AMMCs, the characteristics and application of AA7050, Al2O3, ZrB2, MNCNT, hybrid composites and are also discussed. The next chapter detailly illustrates the various research works carried work in MMCs, the various reinforcements used, the various tribological and metallurgical test carried out in various types of metal matrix composite and hybrid composites.

II. LITERATURE REVIEW

Sathish & Karthick (2020) have used AA7050 aluminium alloy is a base material with Silicon Carbide (SiC) reinforcement at different percentages. To optimize the process parameters, the wear of these composites is studied through the design of experiments (Taguchi approach). The parameters of the wear analysis are sliding velocity, sliding distance and composition percentage. The sliding distance is the most critical element out of three for this experimental investigation. The study of the microstructure shows that there is a SiC particle that decreases specimens wear. Aditya Ranganathan et al. (2018) have explained the mechanical properties of TiC reinforced with AA 7050 metal matrix composites. The stir casting method has used to prepare the Tic based aluminium metal matrix composite. The experimental result indicates that the ultimate tensile strength and hardness properties are enhanced as reinforcement increased. The optical microscopy technique analyses the specimen microstructures, and the microstructure showed uniform particle distribution and reinforcement presence in the matrix material. The results show that the decline in ductility and percentage of elongation as reinforcement increased. Venkatesan & Anthony Xavior (2019) were manufactured Aluminum alloy AA7050 based metal matrix composites reinforced with graphene nanoparticles using stir casting and squeeze casting techniques. Mechanical characteristics examinations are conducted on the prepared composites. The microstructural result indicates that graphene particles are only distributed evenly in composites with 0.3wt % graphene in the aluminium matrix, regardless of the procedure followed for composite sample manufacturing. Cluster formation occurred by increasing the graphene content beyond 0.3wt %.

III. EXPERIMENTAL DETAILS

The experimental methods and materials are briefly discussed based on objectives and methodologies discussed in the previous chapter. This chapter addresses the selection of materials and the preparation of test specimens from the casted samples. It also addresses the casting system, casting parameters, reinforcement weight percentages, pin-on disc wear input process parameters and procedures implemented in this work. It also described the details of sample preparation and test equipment's used for different mechanical examinations such as tensile testing, impact testing and hardness testing. The corresponding ASTM standards for various tests are also discussed in detail. In this research work, AA7050-T7451 is selected as matrix materials and reinforced with different weight percentages of Al2O3, ZrB2 and MWCNTs to increase the wear resistance and enhance the mechanical properties for aircraft wing spar applications.

Fig 1 Photographic image of AA7050 -T7451

All samples have prepared in the following two routes. Initially, ZrB2 and Al2O3 are introduced in the traditional route, and MWCNT's are injected and stirred in different temperatures to enhance the wettability between reinforcements and matrix. Crucible was allowed to vibrate and preheated at 600oC, and then aluminium alloy 7050 is melted at 700oC. The Preheated ZrB2 and Al2O3 were mixed with aluminium melt then stirred at speed 450 – 550 rpm for about 0.28 h to 0.30 h. The MWCNT's were injected with argon gas to the semi-solid aluminium melt then stirred at 250 – 350 rpm for about 0.30 h to 0.34 h to enhance the good wettability of MWCNT's.

IV. PHYSICAL, MECHANICAL PROPERTIES AND METALLURGICAL CHARACTERIZATION OF AA7050/ AL_2O_3/MWCNT HYBRID COMPOSITES

This section illustrates the results of physical properties like density, Mechanical Properties such as tensile, hardness, impact strength and Metallurgical on the developed AA7050/Al_2O_3/MWCNT Hybrid Composites. The results of theoretical and experimental densities of composites containing 1,2,3,4 and 5wt.% of Al_2O_3 particles with 0.5,1 and 1.5 wt.% of MWCNTs Hybrid Composites are discussed and compared with AA7050 matrix.

Density of AA7050/1-5 wt.%Al_2O_3/0.5wt.%MWCNT hybrid composites

The results of theoretical and experimental densities of AA7050 alloy and the hybrid composites containing 1,2,3,4 and 5wt.% of Al_2O_3 particles with 0.5wt.% of MWCNTs particles. Figure 7.1 clearly shows that both theoretical and experimental densities are increasing linearly as predicted from the rule of Mixture. Although the experimental densities have seen a linear rise and the values are lower than the theoretical densities. The density calculations revealed that some porosity was present in the hybrid composites, which leads to the difference between theoretical and experimental densities.

Theoretical and Experimental density of AA7050/1-5 wt.% Al_2O_3/0.5wt.% MWCNT Hybrid Composites

The density of the hybrid composites increased as the weight % of Al_2O_3 particles increases. The theoretical and experimental density values are shown in Table & Figure the theoretical density of AA7050 matrix aterial is about 2.83 g/cm3, and its corresponding experimental density is about 2.825 g/cm3. The difference between these two values is due to the porosity, which is about 0.005%. Similarly, the experimental and theoretical densities of the hybrid composite containing 5wt.% of Al_2O_3 with 0.5 wt.% of MWCNT is 2.989 g/cm3 and 3.00286 g/cm3, respectively.

Table Comparisons of theoretical and experimental densities of AA7050/1-5 wt.% Al_2O_3/0.5wt.% MWCNT Hybrid Composites

S. No.	Material	Theoretical Density (g/cm^3)	Experimental Density (g/cm^3)
1	AA7050	2.83	2.825
2	AA7050+1wt.% Al_2O_3+0.5 wt.% MWCNT	2.86296	2.856
3	AA7050+2wt.% Al_2O_3+0.5 wt.% MWCNT	2.8967	2.889
4	AA7050+3wt.% Al_2O_3+0.5 wt.% MWCNT	2.93124	2.923
5	AA7050+4wt.% Al_2O_3+0.5 wt.% MWCNT	2.96662	2.957
6	AA7050+5wt.% Al_2O_3+0.5 wt.% MWCNT	3.00286	2.989

Tensile test results

The Tensile Strength results of the hybrid composite containing 1,2,3,4 and 5wt.% of Al_2O_3 with 0.5wt.% of MWCNT Hybrid composites are illustrated in Figure 7.5. Figure 7.5 reveals the linear increment of tensile strength on the hybrid composite containing 1,2,3,4 and 5wt.% of Al_2O_3 with 0.5wt.% of MWCNT due to the presence of MWCNT and Al_2O_3 reinforcement particles in the AA7050 matrix material.

The higher tensile strength is obtained from the hybrid composites containing 5wt.% of Al_2O_3 with 0.5wt.% of MWCNT is about 180.54Mpa, which is 4.46708% higher when compared to the AA7050 matrix material. Similar results are identified by various researchers (Ezatpour et al. 2016).

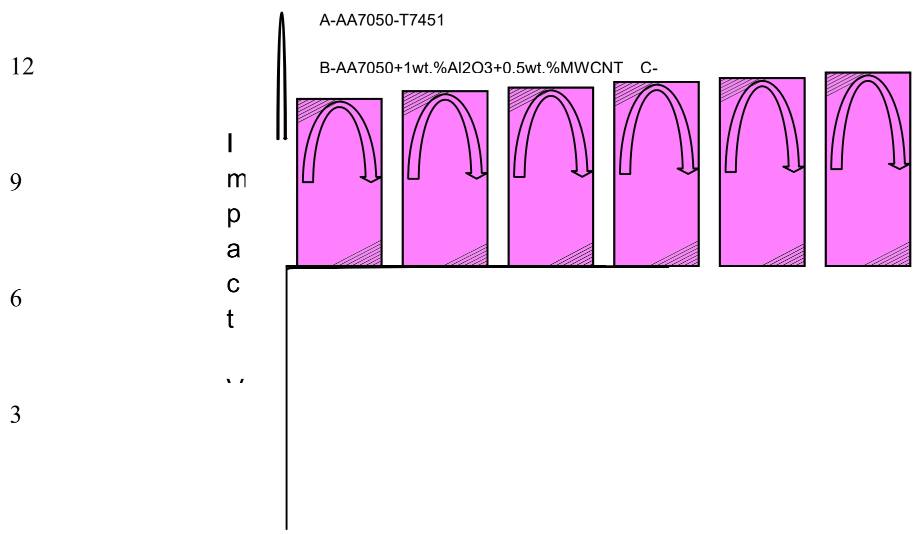
Hardness test results

the Micro Hardness values of the hybrid composite containing 1,2,3,4 and 5wt.% of Al_2O_3 with 0.5wt.% of MWCNT. The linear increase in the hardness values are observed in this test is due to the presence of Al_2O_3 and MWCNT reinforcements in the aluminium matrix 7050. The key factor for the enhancement of hardness value is due to the density of the Al_2O_3 particles presence in the hybrid composites, which is higher than the AA7050 matrix material.The maximum microhardness values of the hybrid composites containing

5wt.% of Al_2O_3 with 0.5wt.% of MWCNT is about 114.59 VHN,which is 7.41271% higher than the AA7050 matrix material. To determine the effect of reinforcements, hardness tests were performed on the composites and compared with base matrix material (Sri Ram Murthy et al. 2019).

Impact test results

The results of Izod impact examinations of the composite containing 1,2,3,4 and 5wt.% of Al_2O_3 with 0.5wt.% of MWCNT Hybrid composites are revealed in Figure 7.7. The influence of impact strength values was progressively enhanced with increased weight %of Al_2O_3 and MWCNT reinforcements. The test results show that the impact energy of the metal matrix composite depends predominantly on the distribution of the Al_2O_3/MWCNT particles in the AA7050 matrix.



V. CONCLUSION

This section summarizes the results of physical properties like density, Mechanical Properties such as tensile, hardness, impact strength, Metallurgical Characterization, tribological wear and RSM based Optimization and Prediction of various input process parameters on the developed AA7050/Al2O3/MWCNT Hybrid Composites.The following three hybrid composites, containing 1wt. % of Al2O3 with 1wt. % of MWCNT, 1wt. % of Al2O3 with 1.5 wt. % of MWCNT and 2wt. % of Al2O3 with 1.5 wt. % of MWCNT are identified as low-density composites because of the higher weight percentage of MWCNT than the Al2O3 particles as reinforcements. The lower tensile strength is observed in matrix material is about 172.83Mpa. The maximum tensile strength value is obtained in developed hybrid composite containing 5wt. % of Al2O3 with 1.5wt.% of MWCNT is about 182.1 Mpa,

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