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Analysis of Damping and Wear Characteristics of Tungsten Carbide reinforced AA6061 Composites

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Abstract

In this research, vibration damping property and dry sliding wear resistance of tungsten carbide reinforced aluminium AA6061 composites were investigated. The fabrications of test specimen were carried out using stir casting method. Three samples were taken for study with percentage of reinforcements as 0%, 4% and 8% of tungsten carbide by volume fraction. The samples are cut and machined to cylindrical pin as per ASTM standard for pin-on-disc wear analysis. Another set of samples with rectangular cross section is used as beam for experimental modal analysis using Impact hammer test to study the damping factor and natural frequency. Based on the test results, it was found that there is minimum wear resistance in reinforced alloy when compared to unreinforced alloy and also reinforced alloy had improved coefficient of friction. From the impact hammer test, the result shows that reinforced alloy had high natural frequency and improved damping factor when compared with unreinforced alloy. The hard ceramic tungsten carbide particulate improves the resistance to wear as well as improved the damping behaviour. This research can be helpful in many industrial application, heavy machineries, automotive applications This material can be developed to use as machine base, chassis where wear resistance and vibration damping needs to predominantly monitored.

Keywords: Aluminium AA6061, Tungsten carbide, wears Analysis, Damping factor.

1. Introduction

Aluminium is light weight material and abundantly available in nature. But aluminium is mostly used in forms of graded aluminium alloy in industry. Aluminium Alloy AA6061 graded alloy is high strength alloy which possess good tensile strength. Tungsten Carbide is the hard ceramic material and available in form of powder. Metal matrix composites are combination of metals reinforced with ceramic powders or metal powders. AA6061 aluminium alloy when reinforced with hard tungsten carbide powders enhances the property of the material. Surface wear is one of the major problems in many engineering components and it reduces the life of the component. Many researchers develop the material to investigate the surface wear and wear morphology of the material. Wear behaviour of Titanium Borate reinforced with AA6061 was investigated and reported wear resistance improved with addition of Titanium Borate material [1,2]. Silicon carbide reinforcements with AA6061 material also enhances the wear resistance as reported in literature.[3]. Nickel particulate reinforced with Aluminium-Silicon composites enhanced the wear behaviour is reported by Veeresh kumar et.al.[4]. Boron Carbide, Molybdenum Sulphide, Muscovite, Waste Porcelain are other reinforcement materials which when reinforced with soft aluminium matrix enhances the wear behaviour of the composites as reported in many literatures.[5-10].Vibration damping is one of the important requirements of the material when using it as machine base, frame, mountings and other supports. If the material's resistance to vibration or absorption of vibration energy is predominant, the ill effects in the mechanical systems will be greatly minimized [11-14].Vibration properties like damping factor and natural frequency of the Aluminium based composites were investigated by many researchers and reported that the reinforcements enhances the natural frequency and damping factor [13-17].

Mechanical behaviour like tensile, compression and flexural behaviour is analyzed with tungsten carbide reinforced aluminium composites [2] but no one reported wear and vibration analysis of tungsten carbide reinforcements with AA6061 aluminium alloy. Hence an effort is made to analyse the vibration behaviour and wear behaviour of the material.

2. Materials and methods

Aluminium Alloy AA6061 is procured in the form of extruded rods and cut into small pieces. Tungsten carbide is procured in the form of powders of average grain size 3 to 5 microns. The fabrication of samples was carried out using Stir casting process. The cut AA6061 samples are preheated in a furnace for about 300˚C. Tungsten carbide particles were preheated to about 400˚C in another furnace. Preheated Aluminium alloy is transferred to the Stir casting machine and gradually increases the temperature till the melting point of the Aluminium alloy of about 600˚ C. Preheated Tungsten carbide is weighed for 4% and 8% of volume fractions. The first set of mould is fabricated without any reinforcing material. The molten material is transferred to the mould of standard size 200 x 150 x 10 mm. The process is repeated for second mould and third mould where 4% and 8% of Tungsten carbide is added as reinforcement respectively. Stirring time is about 10 minutes with Stirring speed of 300 rpm is maintained while adding reinforcement to get uniform dispersion of material throughout the mould. Fig1a&b depicts the fabrication of reinforced AA6061 composites. The fabricated sample are cut and machined as per ASTM Standards.

Two samples of each composition were taken and average values were considered for evaluation. Wear test is carried out in Pin-On-Disk tribometer. Another set of specimen were made for Impact hammer cantilever beam vibration analysis test. The arrangement of Pin on disc tribometer and Impact hammer test is depicted in Fig.2 and 3 respectively.

Fig.1a **Fig.1b**

Fig.1a Molten metal in stir cast furnace

Fig.1b Solidification of metal in mould

Fig.2 Pin-On-Disc Tribometer

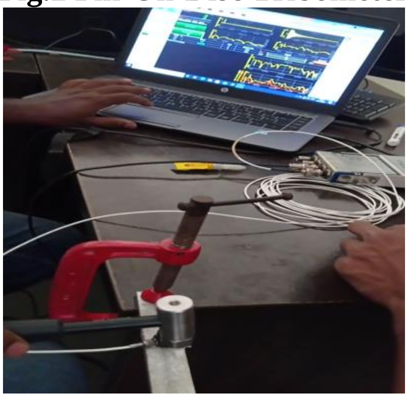

Fig.3 Impact Hammer test

2.1 Method for wear test

The specimen for wear test is of dimensions with 6mm in diameter and 30 mm in length were machined as per ASTM G99 standards. Six samples were made with two samples on each composition were fabricated. The fabricated specimens were subjected to wear analysis on Pin on disc tribometer for a sliding distance of 400m. The diameter of the pin is set at 25mm on the disc made of EN31 Steel. The disc is made to rotate at 382 rpm calculated from the set linear velocity of 0.5 m/sec. The pins are exposed to the wear for about 800 seconds with a load of 5 N and 10 N. The mass loss of the pin after the wear analysis is calculated wear rate is plotted with respect to time. Based on applied load, coefficients of friction of the samples were calculated.

2.2 Method for vibration test

Two samples with specimen size of 150 mm x 20 mm x 10 mm size were fabricated on each composition to conduct Cantilever beam mode Impact hammer test. The fabricated specimen is subjected to test by fixing the specimen at one end and impact hammering at equal intervals on open ends. The frequency response function of the impact specimen is recorded through software called Dewesoft and it records the peak amplitude and natural frequency occurring at the peak amplitude. Damping factor of the specimen also recorded by the software and plots the frequency versus amplitude curve for all the samples.

3. Results and Discussions

3.1 Effect of Reinforcements on Wear rate:

Wear rate and coefficient friction values obtained for various compositions of composites are tabulated in Table.1. From the results, it was evident that additions of tungsten carbide reinforcement enhance the wear resistance and the results are in good agreement with few literatures [3][5]. The plot obtained from the pin-on-disc tribometer's software is depicted in fig.4 a to c. The wear rate of the material with respect to time varies with peaks and downs and total wear of the material remains lesser in reinforced composites when compared to unreinforced composites. The mechanism of wear resistance in the composites is due to the presence of hard ceramic particulates which resists the dislocation. When the surface is being continuously stressed on the surface, hard tungsten carbide ceramic particulates embedded in the soft aluminium matrix resists the movement and enhances the resistance to wear. Similar results had been reported in literature. [7-12]

3.2 Effect of Reinforcements on Damping:

The damping factor and the natural frequency of the unreinforced and reinforced composites are as presented in Table.2. From the results, it can be observed that there is an increase in natural frequency and improvement in damping factor for reinforced composites. The results are in good agreement with few of literatures. [13][15]

Table.1 Wear and Coefficient of friction values for various compositions of composites.

S No	Composition	Total Wear (microns)	Coefficient of friction
1	Unreinforced	550	0.471
2	4% WC	140	0.636
3	8% WC	65	0.671

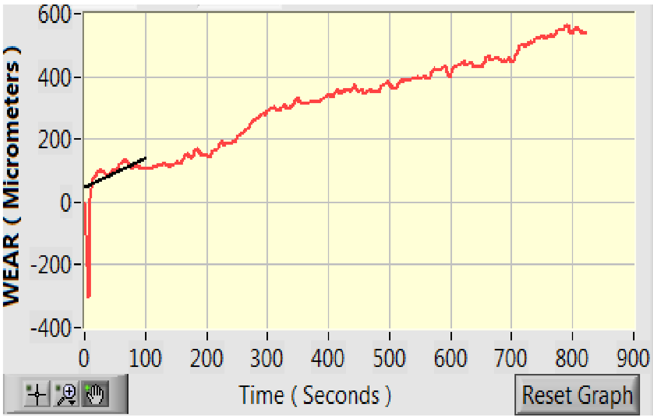

Fig.4 a Wear Versus Time plot for unreinforced alloy

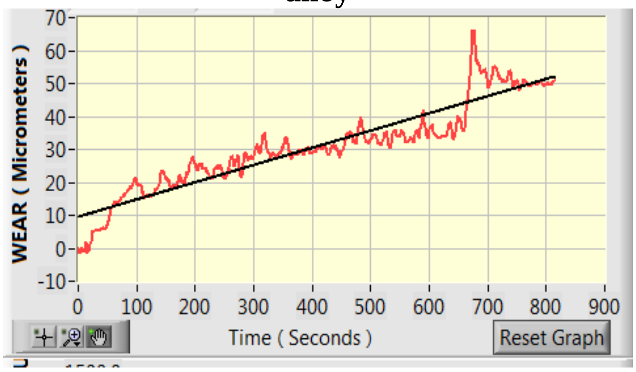

Fig.4 b Wear Versus Time plot for 4% WC reinforced composite

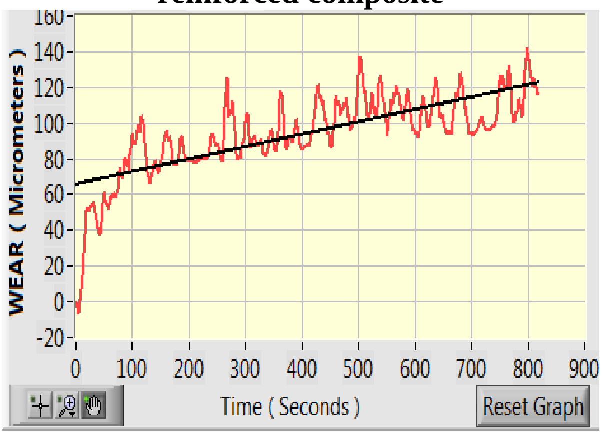

Fig.4 c Wear Versus Time plot for 8% WC reinforced composite

Table. 2 Natural frequency and Damping factor values for various compositions of composites

S. No	Composition	Natural frequency (Hz)	Damping factor
1	Unreinforced	160.64	0.066
2	4% WC	164.37	0.081
3	8% WC	205.62	0.106

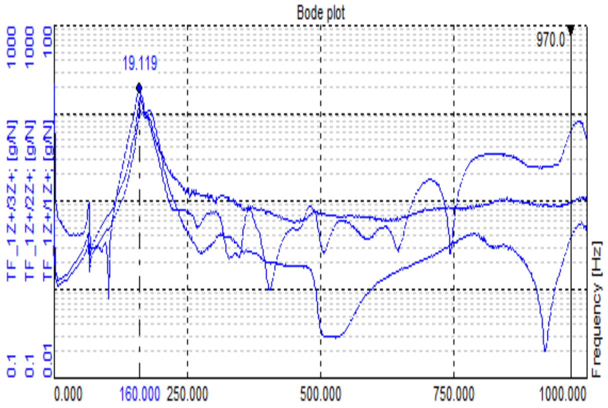

Fig.5.a Bode plot for unreinforcedd composites

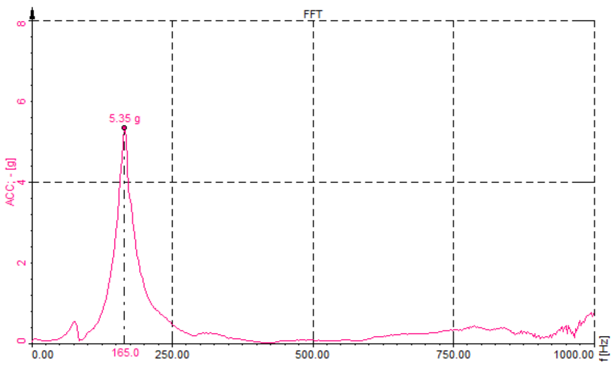

Fig.5.b Bode plot for 4% WC reinforced AA6061 Composites

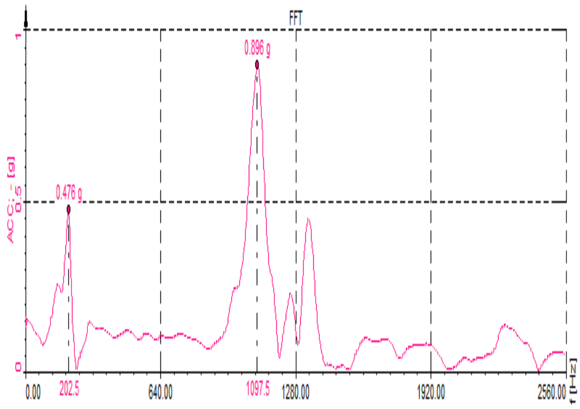

Fig.5.c Bode plot for 8% WC reinforced AA6061 composites

Bode plot is the plot representing the first natural frequency at the first peak amplitude. Fig.5 a to c represents the Bode-plot for all three composition of the composites. The first peak's natural frequencies were notified and the average frequency values were taken for calculating the damping factor. Damping factor is the ratio of actual damping to the critical damping coefficient. It is a measure of how efficient the material can damp out the vibrations. Higher the damping factor, the better damping will be the result. In the same fashion, higher the natural frequency, amplitude will be lower and hence supports the damp out vibration efficiently. From the results, it is evident that the reinforcement of tungsten carbide enhances the damping property of the material.

The mechanism behind the improvement of damping property is analyzed with reference to literature [16][17]. The forfeiting of ceramic reinforcement like tungsten carbide absorbs the impact energy and release lesser amount of the energy. While impacting during impact hammer testing, the amount of energy absorbed during test is high due to the presence of tungsten carbide particulates. Hence, the peak amplitude during the testing will be minimum at the first hit and subsequently it gets reduced [15][17]. Higher the volume of tungsten carbide particulates, the more energy gets absorbed and improved the damping behaviour of the composites.

Conclusion

Metal matrix composites were made through stir casting process with hard ceramic tungsten carbide particulates as reinforcement material through stir casting process and subjected to wear and vibration analysis. The following observations were made during the tests

- Wear resistance and coefficient of friction of reinforced composites improved when compared with unreinforced material.
- Damping factor and Natural frequency of reinforced composites improved when compared with unreinforced aluminium alloy.

From this research, it may be concluded that this material can be developed in building material required passive damping like chassis, frame, machine base etc. where the energy absorption improves the performance of material. Also, this material can used in automobile component development. In future, additions of two or more ceramic particulates can be added to enhance the mechanical, Tribological and dynamic properties of the composites.

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