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Analysis of Dynamic Behaviour and Mechanical Properties of Aluminium Metal Matrix Composites

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Abstract - *Metal matrix composite is found to be the best alternative to replace the conventional materials like steel, brass, aluminium etc. Our main objective is to develop a aluminium based metal matrix composite with a judicious combination of toughness and stiffness to decrease the sensitivity to cracks and flaws and at the same time increases the static and dynamic properties. In this work, the metal matrix alloy of aluminium - 6061 are reinforced with silicon carbide and tungsten carbide through stir casting method and are studied on the basis of the results of impulse frequency test and mechanical properties such as tensile, micro hardness, wear resistance by varying the mass fraction of silicon carbide (SiC) and tungsten carbide (WC) ceramic powder. Based on the results, the composite of aluminium 6061 reinforced silicon carbide at 3% and tungsten carbide at 3% has improved dynamic behaviour and mechanical properties compared with other combinations of reinforced particles with aluminium metal matrix.*

Key Words: Aluminum-6061, Silicon carbide, Tungsten carbide, Dynamic behaviour, Stir casting, mechanical properties.

1. INTRODUCTION

In an ever developing society like ours, we all depend on composite materials in some point of our lives. A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined produce a material with characteristics different from the individual components. Metal matrix composites have gained more attention in recent times. Metal matrix composite is a material consists of a metallic matrix combined with a ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) dispersed phase. The reason why aluminium is chosen as the matrix material is due to its unbeatable strength to weight ratio. Corrosion resistance is an added bonus, eliminating the need for heavy and expensive anti-corrosion coatings and its use of light weight application in various transportations where absorption of vibration is a concern. Due to the improved potential of aluminium metal matrix composites it can be used in brake rotors and brake drums, where improved damping is essential and its resistance to wear overtime and also can be used in the fabrication of valve trains, piston rods and piston pins, etc. The work from the references [1] & [2] are also considered for comparison.

1. Production of Metal Matrix Composites

The composites are produced via stir casting method. The aluminium 6061 is melted to a molten state in the furnace by increasing the furnace temperature upto 850°C. The reinforcements silicon carbide and tungsten carbide are added in different proportions (SiC/WC – 3%/1%, 3%/2%, 3%/3%) and stirred at 800 rpm by a single stage impeller for 15 – 20 minutes. Then it is down poured into the die of test sample dimension for casting and left to solidify and cooled for about 20 minutes. The samples were cast into dimensions of 210mm*20mm*6mm.

2. Analysis

The samples are prepared for Impulse frequency test, micro hardness test, tensile test and wear resistance test to analyse the changes in the characteristics and properties of the composites.

2.1 Impulse frequency test

In this test, dynamic behavior (i.e) the natural frequency and its relation between amplitude and damping capacity(factor) of the composites are analysed. The setup consists of a impact hammer, accelerometer and data acquisition system which converts the so tested vibrational signals into the desired outputs via FFT method using RT pro software. The frequency response graph is shown below.

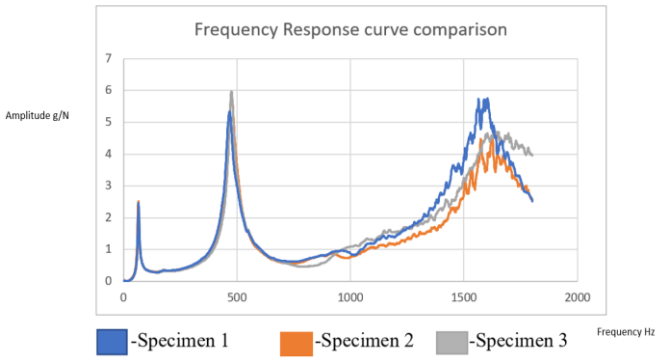
Table -1: Impulse frequency test of Al/SiC/WC

Material specimen	Characteristics	Peak 1
Al-96%, SiC-3%, WC-1%	Frequency Hz Amplitude g/N Damping %	91 2.47 4.62

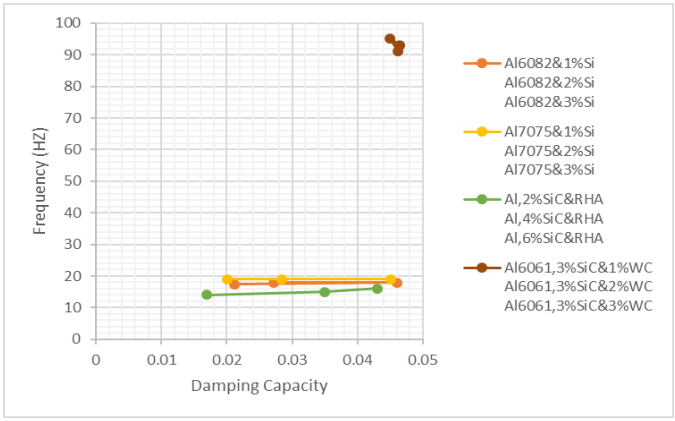
Al-94%, SiC-3%, WC-2%	Frequency Hz Amplitude g/N Damping %	95 2.3 4.5
Al-94%, SiC-3%, WC-3%	Frequency Hz Amplitude g/N Damping %	93 2.46 4.65

Table – 2: Al/SiC/WC vs other composites

Composition	Damping Capacity	Frequency
Al6061,3%SiC&1%WC	0.0462	91
Al6061,3%SiC&2%WC	0.045	95
Al6061,3%SiC&3%WC	0.0465	93
Al6082&1%SiC	0.02123	17.408
Al6082&2%SiC	0.04608	17.92
Al6082&3%SiC	0.02716	17.92
Al7075&1%SiC	0.02009	18.944
Al7075&2%SiC	0.02841	18.944
Al7075&3%SiC	0.04503	18.944
A356.2 Al,2%SiC&RHA	0.017	14
A356.2 Al,4%SiC&RHA	0.035	15
A356.2 Al,6%SiC&RHA	0.043	16



Graph 1 – Frequency response comparison within specimen



Graph 2 – Al/SiC/WC vs other compositions

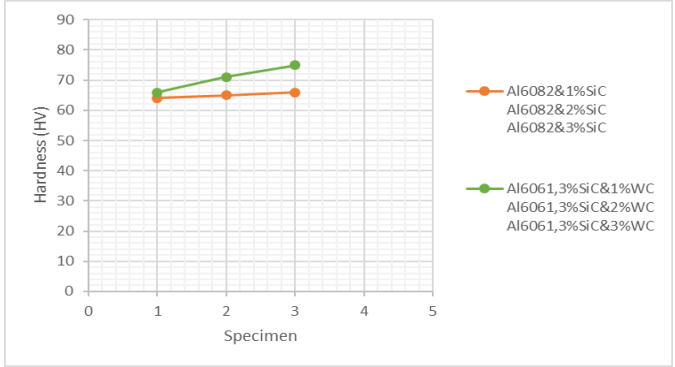
From the above graphs we are able to conclude that the natural frequency of the composites increase with the addition of tungsten carbide and the specimen with SiC/WC - 3%/3% has the better damping capacity and improved natural frequency over the work of ref [1] & [2] where the same analysis is done without tungsten carbide as reinforcement. Thus the situation to reach resonance in this composite highly reduces.

2.2 Micro hardness test

The micro hardness test (Vickers hardness test) were conducted on three samples for each metal matrix composite. The tensile test was carried out in IS 1501 testing method under 0.5 kg load.

Table – 3 : Hardness of Al6061/SiC /WC vs other composites

Composition	Specimen	Hardness (HV)
Al6061, 3%SiC&1%WC	1	66
Al6061, 3%SiC &2%WC	2	71
Al6061, 3%SiC &3%WC	3	75
Al6082&1%SiC	1	64
Al6082&2%SiC	2	65
Al6082&3%SiC	3	66



Graph 3 – Hardness graph of Al6061/SiC/WC vs other composite

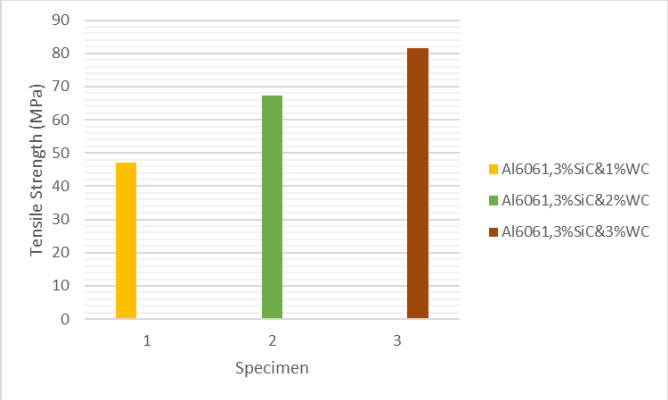
Thus when compared to the results of just SiC reinforced with Al6082, the specimen of Al6061, SiC & WC has shown a increase in Hardness (HV). Also, the Al6061 specimen with composition of SiC/WC at 3%/3% has the better hardness of all weight percentages.

2.3 Tensile test

The tensile tests were conducted on three samples for each metal matrix composite by flat type tensile testing machine. The tensile was carried out in ASTM E8 16a testing method.

Table – 4 : Tensile test results

Composition	Specimen	Tensile Strength in Mpa	Yield stress in Mpa	Elongation in %
Al6061, 3%SiC&1%WC	1	47.16	37.68	6.72
Al6061, 3%SiC &2%WC	2	67.31	52.06	10.26
Al6061, 3%SiC &3%WC	3	81.62	50.16	7.62



Graph 4 – Tensile strength of Al6061/SiC/WC

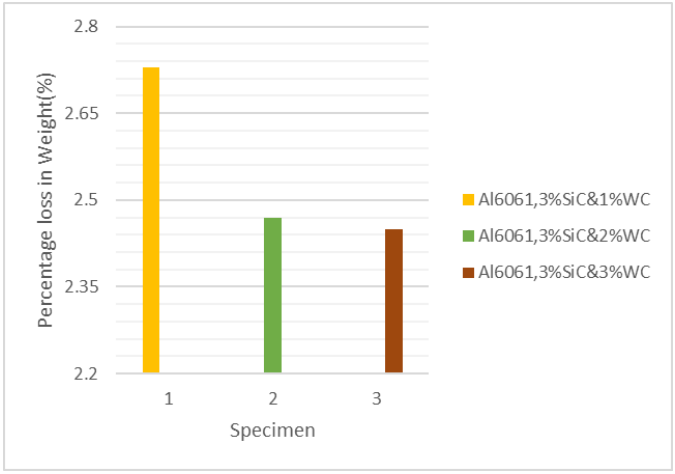
The sample with 3% addition of tungsten carbide to the Al6061 and SiC 3% shows high tensile strength of all weight percentages.

2.4 Wear resistance test

The wear resistance analysis is done by pin -on- drum wear method. Here the wear resistance of the composites are analysed on the basis of percentage loss in the weight after the test.

Table – 5 : Wear resistance test results

Composition	Specimen	Initial Weight (g)	Final Weight (g)	Abrasion Loss (g)	% loss in weight
Al6061, 3%SiC &1%WC	1	2.7396	2.6649	0.0747	2.73
Al6061, 3%SiC &2%WC	2	3.0883	3.0121	0.0762	2.47
Al6061, 3%SiC &3%WC	3	2.9996	2.9261	0.0735	2.45



Graph 5 – Wear resistance test

The sample with 3% addition of tungsten carbide to the Al6061 and SiC 3% shows high tensile strength of all weight percentages.

3. CONCLUSIONS

In this study, Dynamic behaviour and mechanical properties of Aluminium Metal Matrix with Silicon carbide and Tungsten carbide reinforcement of different weight percentage of tungsten carbide at 1,2,3 and a constant weight percentage of Silicon carbide at 3 were examined.

- It was observed that the natural frequency of the composites increases by increasing weight percentage of Tungsten Carbide (WC) particle, when compared within the tested specimen as well as with the considered results of References [1] & [2].
- It was also observed that the Hardness (HV) of the composites tends to increase in weight percentage of Tungsten carbide within the tested specimen and also has shown an increased hardness over the

Al6082/SiC reinforced composites of considered result from Reference [1].

- Tensile strength of composites increases with the increased weight percentages of Tungsten carbide particle within the tested specimen.
- It was observed that the wear resistance of composites tends to increase with the increase in weight percentage of Tungsten carbide along the silicon carbide .

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