ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Investigation on the damping characteristics of AL-NI metal matrix composites

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ABSTRACT

Structural damping is a vital area to be explored during the design of dynamic structures wherein, the selection of suitable structural material is a challenging task for the designer. Aluminium, due to its high strength to weight ratio is used extensively in aerospace and automobile industry. Alloying aluminium with nickel to suit the application of structural damping has vast scope of study. The change in the damping behaviour of the Al-Ni metal matrix composites with the change in the composition is investigated in this paper. Al-Ni metal matrix composite is made by gravity stir casting. Damping ratio is found by free vibration test with an impact hammer and data acquisition systems following standard procedures. The results obtained depict the increase in damping capacity due to addition of nickel with aluminium.

KEY WORDS: Aluminium, MMC, Nickel, Microstructure, Vibration, Damping.

1. INTRODUCTION

The cause for vibration ranges from internal to external influence disturbing the structural stability and integrity. Due to vibrations the intended function of the device is hindered to a larger extent. All materials are capable of dissipating energy during vibration there by aiding in structural damping (Chung, 2001). Damping of vibratory motion is done by active and passive methods. Passive damping is preferred for its simplicity in the device and no external energy is needed. Passive damping methods are by the inherent structural property to absorb energy and dissipate in every cycle of vibration. Metals suits best due to its capability to act as structural support and also to damp vibration (Hui Lu, 2009).

Domain specific applications demands special characteristics and hence forth composite materials complements the need. The interest in metal matrix composites (MMCs) is due to relation of structure to properties such as specific stiffness or specific strength (Hui Lu, 2009). Aluminium matrix composite are not single material but a family of materials whose stiffness, density and thermal properties can be tailored (El-Sayed Youssef El-kady, 2012). Composite materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance, etc. Matrix is the primary phase of an MMC where suitable matrix alloys is mainly determined by the intended application of the composite material. In structural applications, the matrix is usually a lighter metal such as aluminium, magnesium, or titanium, and provides a complaint support for the reinforcement (Rana, 2012). Reinforcement is the secondary phase of an MMC where the reinforcement material is embedded into the matrix. It is used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The damping characteristics (El-Sayed Youssef El-kady, 2012) identified in this paper is calculated through the logarithmic decrement.

2. MATERIALS AND METHODS

Aluminium is the most widely used nonferrous material. Its high strength to weight ratio enables its applicability to various cases[6]. Aluminium is a very light metal with a specific weight of 2.7 gm. /cm^3, about a third that of steel. Its strength can be modified by alloying in various composition. Aluminium also naturally generates a protective oxide coating and is highly corrosion resistant. Aluminium is found to have damping capacity and hence it is considered as a matrix (El-Sayed Youssef El-kady, 2012).

Table.1. Properties of Aluminium 6061

Element	Mg	Si	fe	Cu	Zn	Ti	Mn	Cr	Al & others
% Wt.	0.8	0.6	0.7	0.25	0.25	0.15	0.15	0.20	96

Pure Nickel is reported to be a high damping material[8].Based on the literature review an attempt is made to use nickel as a reinforcement element to aluminium to form aluminium metal matrix composite and its damping characteristics are investigated (Hui Lu, 2009).

Table.2. Properties of Nickel

Property	Value
Melting Point	1728 k
Density	8.908 g/cm^3
Young’s modulus	200 Gpa
Poisson Ratio	0.31

Specimens were prepared by gravity stir casting. The gravity process begins by preheating the mould to 150–200 °C to ease the flow and reduce thermal damage to the casting. The mould cavity is then coated with a refractory material or a mould wash, which prevents the casting from sticking to the mould and prolongs the mould life. The metal is to be placed into the furnace at 800°C for more than 1 hour. Then the reinforcement is to be added to the molten matrix composite. Molten metal is then poured into the mould. Soon after solidification, the mould is opened and the casting removed to reduce chances of hot tears. The process is repeated, but preheating is not required because the heat from the previous casting is adequate and the refractory coating should last several castings. The compositions followed during the specimen preparation are shown in table 3. After casting, the specimen is cut for length of 200mm, breadth of 25mm, and thickness of 6 mm and finished by grinding process.

Table.3.Composition of Metal matrix composite

Specimen No.	Aluminium in %	Nickel in %
1	100	-
2	99	1
3	97	3

3. EXPERIMENTAL PROCEDURES

Free vibration tests to predict the damping characteristics (El-Sayed Youssef El-kady, 2012) were conducted by clamping the specimen in a cantilever beam setup. The instruments shown in figure 2 are used for free vibration test. An impact hammer Kistler, Germany, make, with a load rating of 500N, a tri-axial accelerometer Kistler, Germany, make, with a sensitivity of 2.mv/g, measuring range -2000g to +2000g, 16 channel Data acquisition system with vibration module from National Instruments and Lab View software. (Venkatraman, 2015) Giving insight in the spring performance under cyclic loads considering as parameters: material type, wire diameter, recommended time and other Specifications It has been shown experimentally as well, that Static limit depends on the Torsional stress field.

Block diagrams were developed according to the sequence of operations in free vibration test.

Figure.1.Experimental Set-up

The block diagram shown in figure 2 is programmed in Lab view to enable data acquisition, to filter the noise and to convert time domain signals to frequency domain signals.

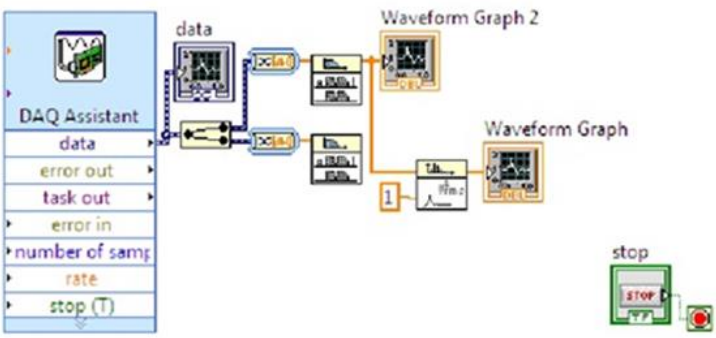

Figure.2.LabView Block Diagram

4. TESTING AND RESULTS

Microstructure analysis: The specimen preparation for the microscopic study was executed by rubbing it emery paper with gradations starting from 1/4, 1/3, 1/2, 1/1. The order of the gradation was according to the roughness from coarse to fine respectively. The microstructure for the specimen was observed and captured at 100X magnification.

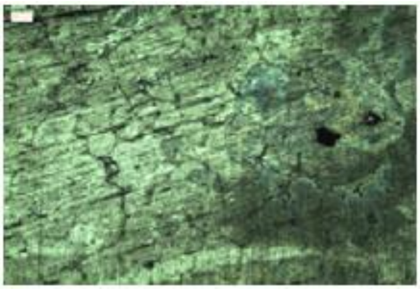

Figure.3.Microstructure of Pure Aluminium

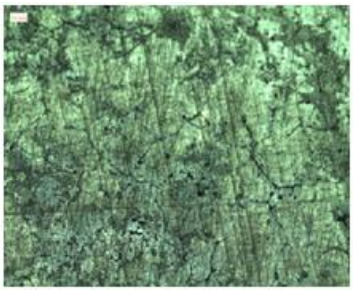

Figure.4.Microstructure of 99% Al, 1% Ni

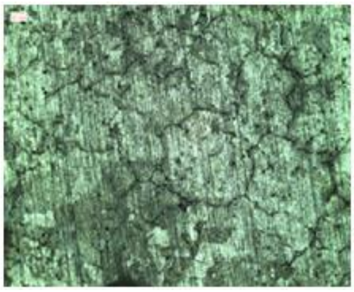

Figure.5.Microstructure of 97% Al, 3% Ni

Microstructure shown in figure 4 and figure 5 indicates uniform distribution of Ni in the matrix resulting in good bonding of the particulates to form the metal matrix composite. The porosity found attributes to the casting defects.

Frequency and damping characterization: Free vibration test with an impact hammer of 500 N. The accelerometer is attached to the specimen for a cantilever beam consideration at the free end. The data acquisition system enables the signals to be processed. Lab View software is used to minimize the noise in signals and to handle the FFT process. Time domain signals obtained are converted into frequency domain signals using the spectrum analyser.

The amplitude - frequency plot obtained from the free vibration test for pure aluminium is shown in figure 7. For specimen No.1, the frequencies are found to be 1150Hz, 2200Hz, and 2950Hz. Lower frequencies are not found in the plot, which can be understood as the influence of fixity conditions during the free vibration test.

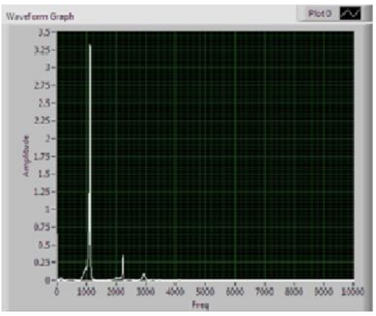

Figure.6.Frequency plot of Pure Aluminium

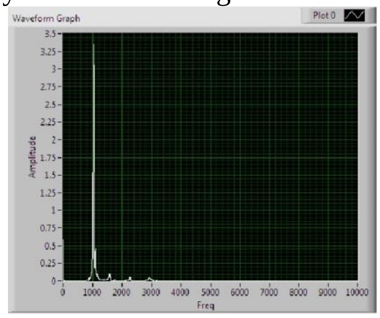

Figure.7.Frequency plot 99% Al, 1% Ni

On adding 1% Nickel and reducing the aluminium as 99%, the frequencies are found to shift, which is shown in figure 7. The frequency plot in figure 8 shows that the higher frequencies are shifted to larger values than 10000 Hz. Effect of Nickel addition to 3% to aluminium 97% is shown in figure 8.

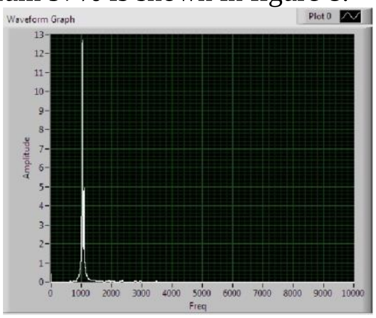

Figure.8. Frequency plot 97% Al, 3% Ni

Damping plots for the three specimens prepared are shown in figure 9, figure 10 and figure 11. Damping plots aids in calculating the logarithmic decrement for each specimen.

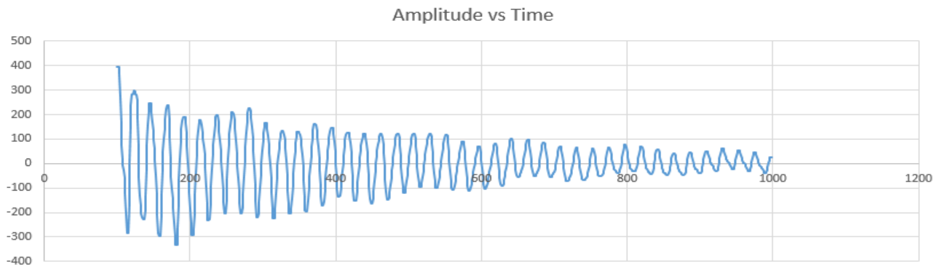

Figure.9.Damping plot of Pure Aluminium

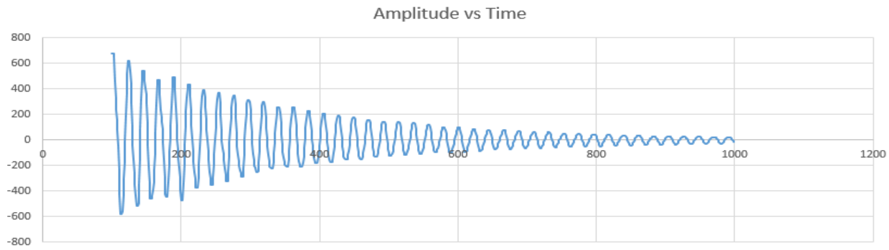

Figure.10.Damping plot of 99% Al, 1% Ni

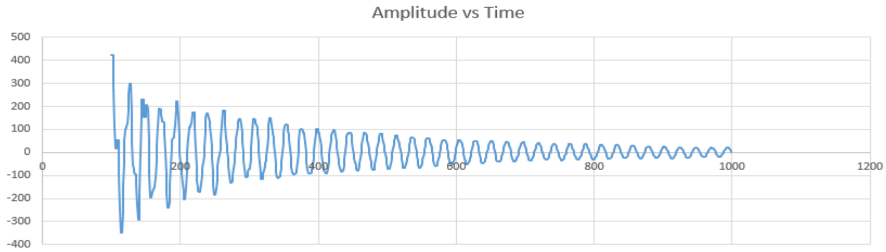

Figure.11 Damping plot 97% Al, 3% Ni

Table.4. Damping ratio

Sample No.	Composition	Natural frequency	Damping ratio
1	100% Aluminium	1171.6	0.0449
2	99% Al + 1%Ni	1044.3	0.12
3	97% Al +3%Ni	1017.0	0.16

Damping ratios calculated are shown in Table 4.The table depicts significant increase in damping ratios with increase in nickel. Hence nickel acts as a reinforcement element and also as a damping agent.

5. CONCLUSION

Structural damping, tailor made by Aluminium nickel metal matrix composites show good damping characteristics. From frequency plots it is evident that higher frequencies can be shifted to larger values by adding high damping materials. By shifting the frequencies to very large values the resonance condition can be avoided, thereby, increasing the survivability of the machines and structures. The increase in damping ratio proves aluminium nickel metal matrix composite to be a structural damping material. As nickel percentage increases the higher frequency also increases, which shows metal matrix composite to be stiffer. Increase in stiffness due to nickel addition, proves nickel to be suitable reinforcement element satisfying the requirement of a metal matrix composite.

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