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Transmissibility, Isolation Region and Damping Characteristics of Gray Cast Iron and Aluminium Composite

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Abstract. All The metal composite was prepared in this research by utilizing waste of aluminum and gray cast iron chips in supporting the global program of sustainable recycling-oriented society. The process was carried out via hot extrusion at 400^{o}C. Three compositions were provided in this research, namely the composition of aluminum chips with addition 0 vol.%, 20 vol.%, and 40 vol.% of gray cast iron chips. Increasing the gray cast iron was found affect on reducing the natural frequency of the product. Addition about 20 vol.% of gray cast iron decreases the value of damping capacity. Conversely, addition about 40 vol.% gray cast iron increases the value of damping capacity significantly. It was also found that the addition of gray cast iron could extend the isolation region and decreased the transmissibility at the isolation region.

1. Introduction

These The material of aluminum and the gray cast iron are widely used, so that also produce a large scale of waste from the manufacturing processes. In relation with supporting the global program of sustainable recycling-oriented society, the waste of aluminum and gray cast iron chips were utilized in this research. The future application of this composite is addressed for functional and useful material such as passive vibration isolator. Gray cast iron was well known as a material that having a high damping capacity, due to flake-like shape of graphite that was contain in its microstructure and widely used as passive vibration isolator [1].
Transmission of unwanted vibration can cause various problems in sensitive system including system malfunction and performance degradation. The common approach to limit the transmission of harmful vibration in the sensitive system is by adapting passive vibration isolator[2]. Since the mechanism of passive vibration isolator was depend on the damping property of the material, it is hoping that the use of gray cast iron chips for passive vibration isolation will come in to a positive result.
The aluminum chips was used asamatrix since known having wide range of plasticity, so that possible to be processed via hot extrusion. Hot extrusion was introduced in this research since previous research proved that this method resulting high damping product [3-4].

2. Experimental

The waste of gray cast iron chips from the type of FC 150 (Compositions in Table 1) was obtained directly from the company of Aishin Takaoka, Japan. The simulation of waste aluminum chips was made by using milling machine with cutting condition at 1005 rpm, feed at 1000 mm/min., with deep of cut at 0.1 mm. The aluminum was from the type of Al 6061-T6 (Composition in Table 2).

Table1. Chemical composition of FC 150.

C	Si	P	S	Mn	Fe
3.1	1.6	0.07	0.05	0.28-1.01	Balance

Table 2. Chemical composition of Al 6061-T6.

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others	Al
0.40-0.8	≤0.7	0.15-0.40	≤0.15	0.8-1.2	0.04-0..35	≤0.25	≤0.15	≤0.15	Balance

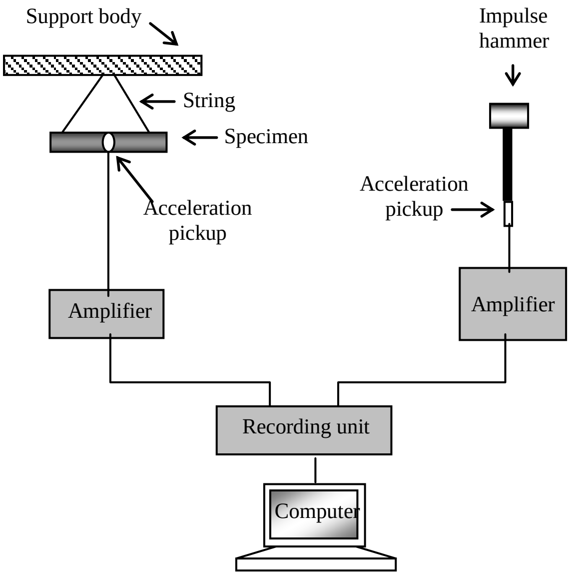


Figure 1.Out line chart of experimentalapparatus.

The chips were cleaned ultrasonically in ethanol, afterward mixed and homogenized in V-type tube mixer. Three compositions were provided in this research namely, composition of Al chips with addition 0, 20, and 40 vol.% of gray cast iron chips. The Process was continued with compacting at 1 MPa to become a billet with 70 mm length and 60 mm in diameter. The billets were then covered with 0.01 mm aluminum foil for hot extrusion preparation. The hot extrusion was carried out at 400^{o}C, with applying pressure at 500 Ton, the speed was arranged at 73 mm/min. The extrusion ratio was 4. The lubricant that was used at the die was MoS_2, mean while the graphite colloid was utilized as lubricant at main cylinder of extrusion. Final diameter of the product was 15 mm.

The damping capacity of the product, natural frequency, and transmissibility were measured by utilizing hammering vibration test. figure 1 shows the outline chart of experimental apparatus. The specimen with diameter 15 mm and 150 mm length was hung, and then hit by using impulse hammer (GK-300, ONO SOOKI). The acceleration pickup sensor at the specimen and hammer transmitted the vibration signal to the amplifier to be forwarded to the recording unit (LX-10, TEAC). The signal data was then extracted to the computer to be analyzed its natural frequency, damping capacity, transmissibility, and the range of isolation region.

3. Results and discussion

The The sampling frequency (fs) was set at 48.000 Hz, with total number of discrete samples (N) that was taken is 4096. The result of damping signal can be seen at figure. 2. The value of damping capacity was expressed by attenuation coefficient (α) and was obtained by fitting the graph to the equation:

$$A(t) = A_o \exp[-\alpha t] \quad (1)$$

A(t) was the amplitude at any time, and initial amplitude was expressed by A_o. As can be seen at figure. 2, the value of α decreased from 25.3[S^{-1}] to become 16[S^{-1}] by adding of 20% gray cast iron, and by adding about 40% gray cast iron the value of α increased surprisingly to become 43[S^{-1}]. As a comparison [5], magnesium was known as a single metal that have high value of damping capacity, and its α value was 30.5[S^{-1}].

To obtain the natural frequency of the product, the time domain at figure 2 should transform to become frequency domain by using a discrete Fourier transform:

$$F(k\Delta f) = \sum_{n=o}^{N-1} f(n\Delta t) e^{-i(2\pi k\Delta f)(n\Delta t)} \quad (2)$$

for k= 0, 1, 2, …, N-1

The time increment between samples wasΔt, and frequency increment wasΔf. The result was a complex number z = x + iy. The magnitude of z was given by $|z| = \sqrt{x^2 + y^2}$.

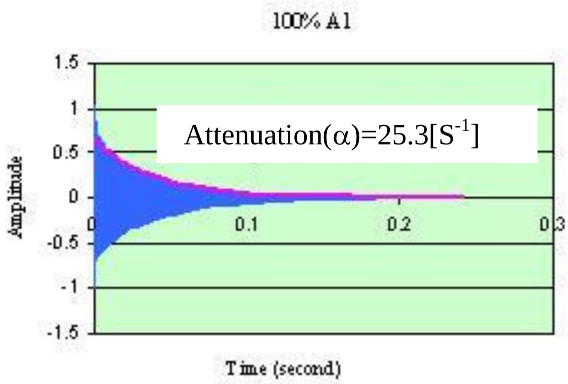
For faster calculation of equation 2, the fast Fourier transforms was utilized in this research. After frequency domain was obtained, the frequency with has highest magnitude at 1st Nyquist zone was mentioned as a natural frequency (f_r) of the product. It was found that the value of natural frequency of the specimen without addition of gray cast iron was 2613.3 Hz.Addition of 20 vol.% gray cast iron make the natural frequency decrease to become 2191.4 Hz., and increasing the gray cast iron content up to 40 vol.% make the value of natural frequency decrease until 2027.3 Hz as can be seen in figure.3.

The value of logarithmic decrement (δ) can be obtained from the equation:

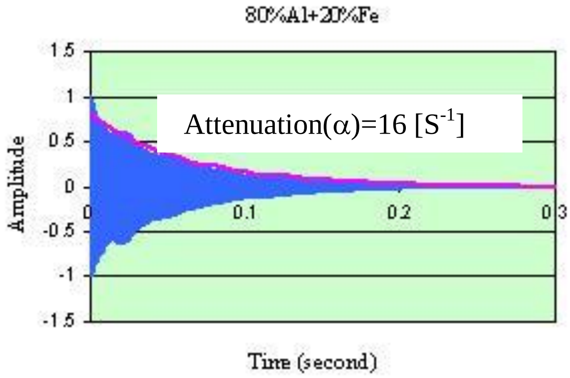
$$\alpha = \pi f_r Q^{-1}$$

$$Q^{-1} = \frac{\delta}{\pi} \quad (3)$$

$Q^{-1}$was an internal friction.



(a)



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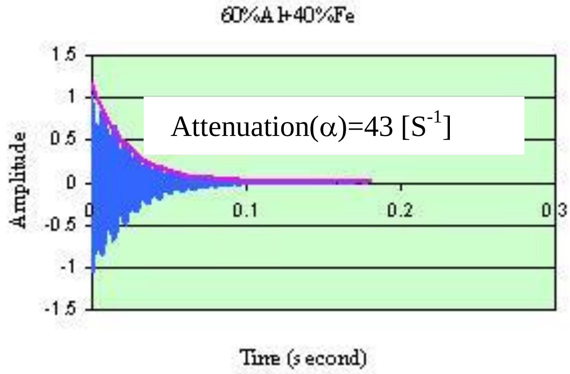
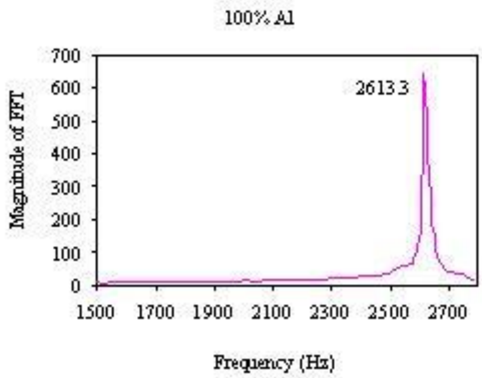
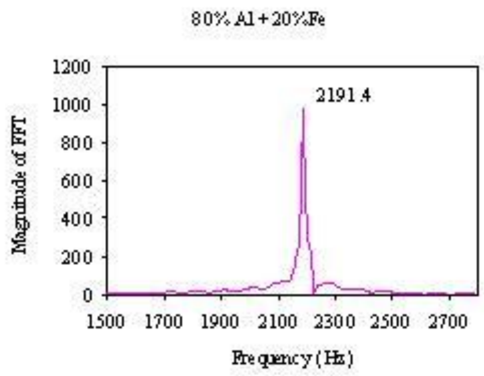


(c)

Figure 2. The damping signal of the product and its damping value that was expressed in attenuation coefficient (α). a.100% Al. b. 80% Al+20%Fe, c. 60% Al+40%Fe



(a)



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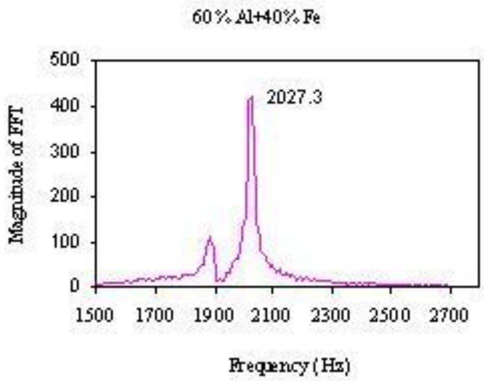

(c)

Figure. 3. The value of natural frequency that was obtained from the Fourier transform. a. 100% Al, b. 80%Al+20%Fe, c. 60%Al+40% Fe.

The value of logarithmic decrement that was obtained from Equation 3 and the value of natural frequency taken from figure. 3 were used to obtain the transmissibility (μ) that was obtained by using Equation 4 suggested by [6,7].

$$\mu = \sqrt{\frac{1+\left(\frac{\delta}{\pi}\right)^2}{\left[1-\left(\frac{f}{f_r}\right)^2\right]^2+\left(\frac{\delta}{\pi}\right)^2}} \quad (4)$$

Where f represent frequency of interest or operating frequency. Isolation region was a region which the value of μ bellow 1. The transmissibility will have value 1 if the value of $\frac{f}{f_r}$ is $\sqrt{2}$.

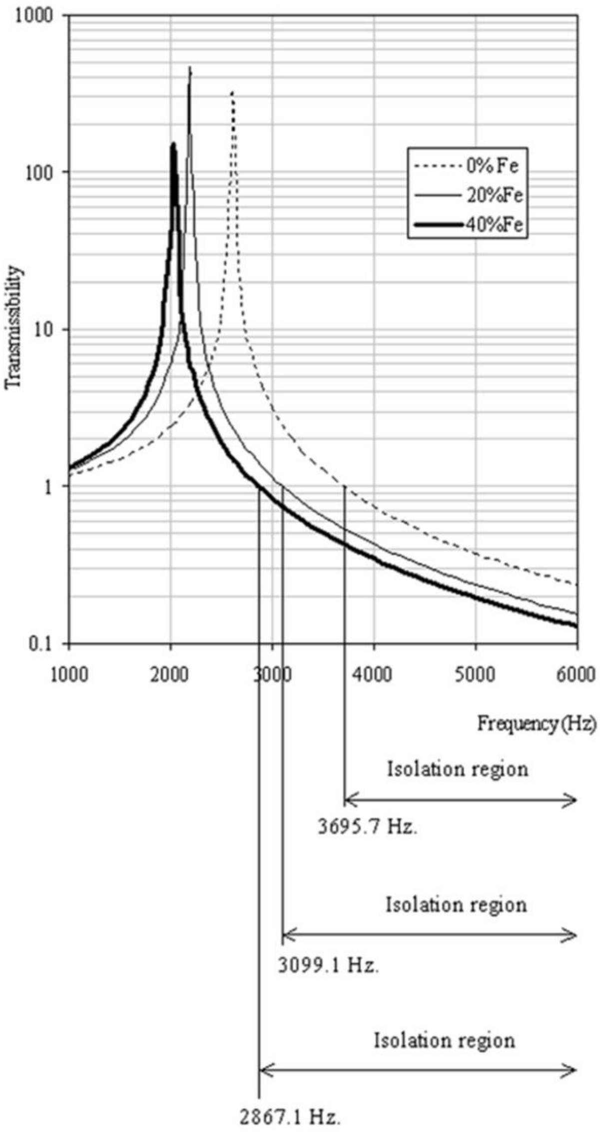

Figure.4. The graph of transmissibility of the product and range of isolation region.

It can be obtained from equation 4, the minimal operating frequency for isolation region for each specimen. As can be seen in figure. 4, for specimen with no addition of gray cast iron the value of minimum operating frequency is 3695.7 Hz. Addition about 20 vol.% gray cast iron make the minimal operating frequency decrease to become 3066.1 Hz. The isolation region was very much increase with addition of 40 vol.% gray cast iron that was caused by the decrease of minimal operating frequency to become 2867.1 Hz. These all mean that addition of gray cast iron can extend the isolation region.

Comparing with transmissibility of gray cast iron from the previous research [8], it was found that the product with addition 40 vol.% gray cast iron seem have similar transmissibility with gray cast iron.

It should be note that the metal composite in this research is dedicated for passive vibration isolator with limitation that the system will work if frequency of the disturbance is around the natural frequency of the composite[9].

In this research, waste of grey cast-iron is used to make a composite wit aluminium. Another waste for future investigation is ductile cast iron. Ductile cast iron will have good properties of damping capacity trough process of austempered[10]. The Damping capacity data from various metal and ceramic is well established[11]but the final result from the composite can not be predicted and should be obtained by experimental investigation.

Beside grey cast iron, shape memory alloys, especially those based on copper, present a different damping capacity on martensite, austenite or transition state [12]. It is good for future investigation to develop new type of passive damping capacity by using waste of copper chips.

This is one of the example success work in manufacturing useful product by utilization waste of metal following previous works [13,14]. It is suggested for the future work to promote recycle, reuses and reduce waste of metal for future sustainability.

4. Conclusion

The conclusions that is obtained in this researchare :Addition gray cast iron affect on reducing the natural frequency. The damping capacity decrease with addition 20 vol.% gray cast iron, and conversely increase significantly by addition of 40 vol.% gray cast iron.The isolation region was extended and transmissibility at isolation region decreased with addition of gray cast iron.

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