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Analysis on Mechanical and Dynamic behavior of Granite Epoxy Composites with Cast Iron Particulates as Filler

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ABSTRACT

The prime objective in performing the machining operations is to procure products with meticulous dimensions and exceptional surface finish. This necessity can be fulfilled by the utilization of precision machine tools for machining processes. The machine tool structure must be composed of materials possessing high damping and high stiffness properties. Cast iron is being used as a structural material for its good damping properties. Granite epoxy composite is an alternative material due to its better damping and static stiffness. In this study, the vibration behavior and mechanical properties of granite epoxy composite are analyzed by using cast iron particulates as filler material. The granite epoxy composite specimens are fabricated as per the ASTM standards by altering the epoxy and granite percentages in composite mixture in addition to 5, 10, and 15% cast iron particulates as filler material. The mechanical properties such as compressive, tensile, and flexural properties have been investigated. Dynamic analysis is carried out to evaluate the damping behavior for various compositions of granite, epoxy, and cast iron particles. The inclusion of cast iron as filler material affects both mechanical and damping properties based on filler content, which has been presented.

Key words: *Granite, Epoxy, Damping, Precision.*

1. INTRODUCTION

Due to environment and sustainability considerations, the evolutions of high-performance materials made have been increasing worldwide. The greatest challenge in working with fiber-reinforced plastic composites is targeting various fields for environmental and economic benefits, which could be used in automotive industry for the development of precision machine tools and in construction of sectors such as walls and roofs. The use of igneous rock, i.e., granite particulate as reinforcement in fiber-reinforced plastics is been receiving greater attention recently because of their advantages such as availability, low density, and high-specific strength. However, there are some disadvantages associated with the use of granite as reinforcement in polymer composites. These include the incompatibility between granite and polymer matrices, tendency to form aggregates during processing, and poor moisture resistance.

Ravindra and Rai [1] analyzed the mechanical characteristics of granite epoxy composite by varying the weight percentages of granite particles. The results obtained were tabulated and compared with other conventional material values. Baskaran and Sarojadevi [2] presented a study based on the usage of granite particles as a filler material in vinyl ester matrix. Various tests are carried out to determine the mechanical, thermal, and chemical properties of the composite. Vinyl ester exhibited lesser thermal properties than the prepared composites. Piratelli-Filho and Shimabukuro [3] carried out an experimental study to analyze the compressive behavior of granite epoxy composite. Factorial design technique is used to perform the set of experiments. Granite particles possess better compressive properties. The superior compression strength values are attained at 80:20 granite:epoxy ratio. Better compression properties are obtained for lesser epoxy percentages. Ramakrishna *et al*. [4] conducted an experimental research on the mechanical characterization of granite epoxy composite. Selvakumar and Ganesan [4] analyzed the effect of structural vibrations developed in precision equipment. Granite epoxy is preferred as an alternate material for a structural system since this composite illustrates excellent damping and superior stiffness values. The damping ratio of granite epoxy is found to be several times larger than cast

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iron. Ramakrishna *et al*. [5] carried out this work to study the behavior of granite particles as a filler material in epoxy. Polybutylene terephthalate is used for strengthening of epoxy resin. Silane is used as a coupling factor for customizing the granite particles. By adding 50% filler material in the matrix, superior mechanical properties are obtained. Bakar *et al*. [6] carried out a work on investigating the mechanical and thermal behavior of epoxy resin composites. To strengthen epoxy resin, polyurethane is added to it. From the test, the toughening of epoxy resin upon the inclusion of modifier has been investigated. Kim *et al*. [7] reported on the utilization of epoxy concrete as base material for machine tool structures. Bhavan *et al*. [8] have reviewed various studies on natural fiber epoxy composites. Based on the literature cited above, the present research endeavor is one such attempt to investigate the dynamic characteristics of granite epoxy composite with and without addition of filler and determining damping factor, logarithmic decrement, and natural frequency of the composites experimentally.

2. METHODOLOGY

The matrix material used in this composite preparation is epoxy resin. The trade name of epoxy resin used is LAPOX L-12 (3202). A curing agent K-6 is used for accelerated curing of resin at room temperature. The reinforcement material chosen for the fabrication of composite specimen is black granite in particulate form. Granular size ranges from 424-599 µm and 53-149 µm is selected. Fine and coarse granules mixed in equal proportion of 50:50 blend together resulting in improved compaction and lessen the porosity level. Measured granite filler is mixed with Lapox L12 epoxy resin and hardener K6 in the ratio of 10:1. This mixture was continuously stirred to give proper gel time of 15 min to obtain better homogeneity. The mixture was then poured into the mold and allowed to cure for about 24 h and later kept in an oven at 60°C for 4 h to accelerate the curing process. The specimens were then kept in room temperature for 7 days for complete curing. Cast iron powder of size ranging from 0-90 µ is used as the filler material. The mechanical and dynamic characteristics of the prepared granite epoxy composite specimen with the inclusion of filler particles have been analyzed. Cast iron particles were added to the composite with 5%, 10%, and 15%. The speed of the test is fixed to 0.5 mm/min. The compression, tensile, and flexural specimens were prepared as per ASTM D695, ASTM D638, and ASTM D790, respectively. All the tests are performed on a UTM of 75 kN capacity, Tinius Olsen Company. The mold for dynamic analysis specimens was prepared using Teflon material with split design for easy removal of the specimen. The size of the specimen was 20 mm × 20 mm × 200 mm. Damping ratios are calculated by half power method from the frequency response curves obtained from dynamic analysis tests on the prepared specimens.

3. RESULTS AND DISCUSSIONS

Figure 1a shows the compressive strength plot of granite epoxy composite specimens without the inclusion of filler material. From the plot, it is observed that the compressive strength of the fabricated specimen's increases up to 70% granite and 30% epoxy content and further decreases with the increase in epoxy percentage. The maximal compressive strength achieved is 112 MPa for 70:30 granite: epoxy ratio. The graph of modulus of elasticity of granite epoxy specimens is shown in Figure 1b. The maximum elastic modulus of compressive specimens recorded is 4.17 GPa for 85:15 granite:epoxy ratio. The modulus of elasticity decreases with the increase in epoxy percentage in the specimen. Thus, larger granite content specimens are stiffer in nature. The characteristic curve of tensile strength of granite epoxy specimens without filler content is plotted as shown in Figure 2a. The plot indicates that the tensile strength of the specimen increases with the increase in epoxy percentage in the specimen. The maximum tensile strength is attained at 39.56 MPa for pure epoxy specimen. This indicates that the addition of granite

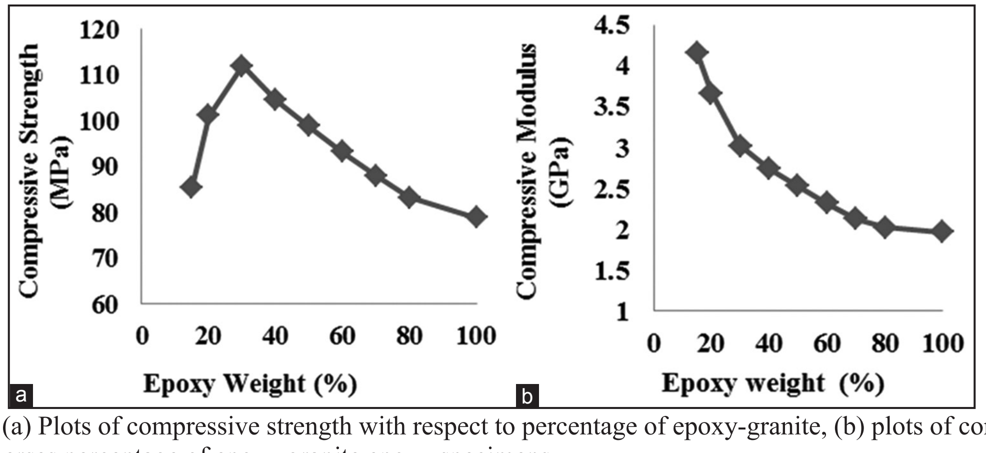

Figure 1: (a) Plots of compressive strength with respect to percentage of epoxy-granite, (b) plots of compressive modulus verses percentage of epoxy granite epoxy specimens.

particles results in the reduction of tensile strength. The specimens indicated a brittle failure, which shows that the granite epoxy composites are weak in tension. The specimen containing 80% of granite content and 20% of epoxy obtained higher elastic modulus values of 6.23 GPa. Pure epoxy composite specimen resulted in a lower elastic modulus value of 1.603 GPa. This indicates that stiffness reduces with reduction in granite and increases in epoxy content. The plot of ultimate flexural strength for granite epoxy specimens without filler material is shown in Figure 2b. From the nature of the plot, it is observed that maximum flexural strength attained is 75.45 MPa for 30:70 granite epoxy ratio. The reduction in flexural strength values is observed with the addition in granite particles in the specimen.

The measured values of compressive strength of specimens with different combinations of granite and cast iron particles by weight percentage are presented in Figure 3a. By analyzing the graphs, we find that the compressive strength of the specimens is higher for 10% addition of cast iron filler material. The maximum compressive strength value obtained is

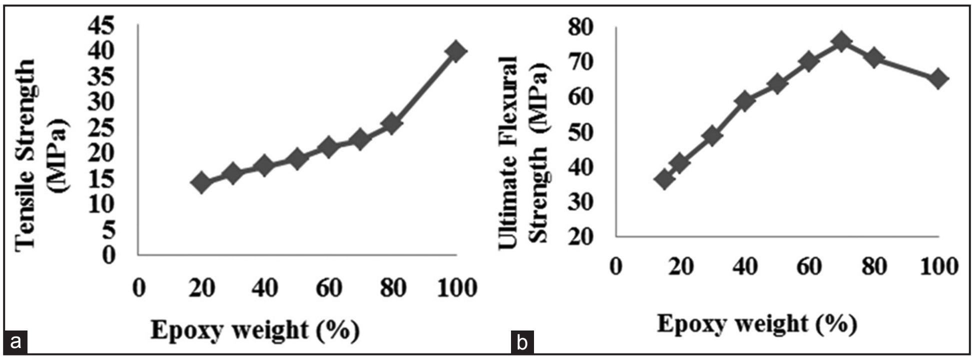

Figure 2: (a) Variation of tensile strength with respect to percentage of epoxy for granite-epoxy, (b) variation of flexural strength with respect to percentage of epoxy-granite.

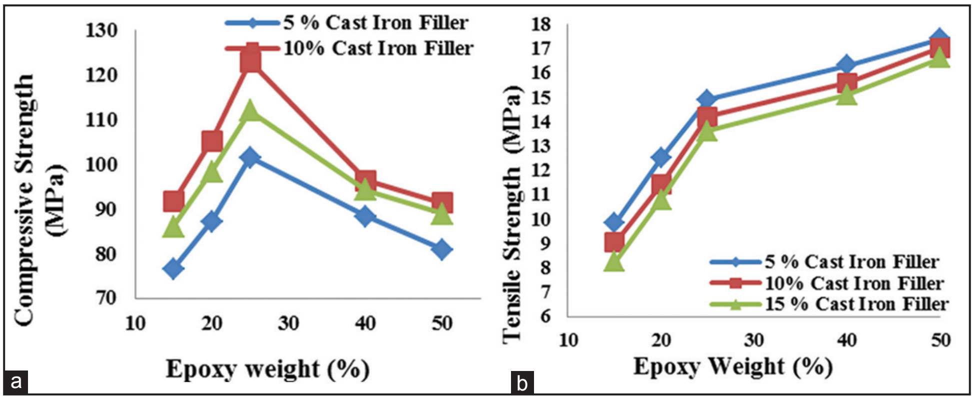

Figure 3: (a) Variation of compressive strength of granite-epoxy test specimens with cast iron filler for various percentages of epoxy, (b) variation of tensile strength granite epoxy specimens with cast iron filler with various percentages of epoxy.

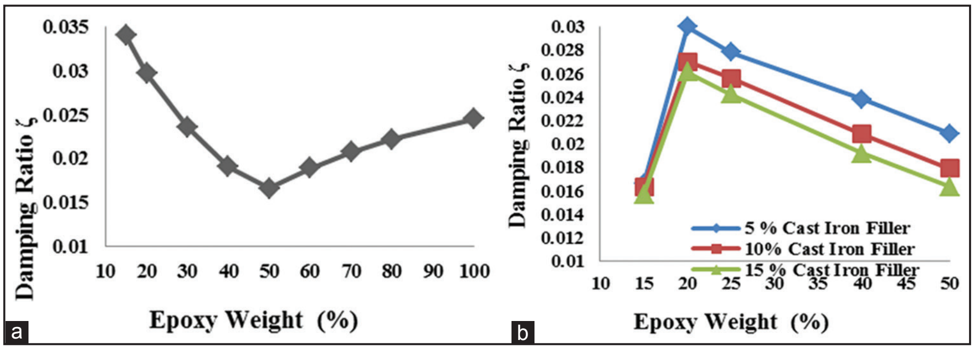

Figure 4: (a) Variation of damping ratio of granite epoxy test specimens, (b) variation of damping ratio of granite-epoxy specimens with cast iron filler for various percentages of epoxy.

123 MPa for 25% of epoxy content with 10% filler material. The modulus of elasticity is found to be higher for 10% of filler material. The elastic modulus of the specimens decreases with the increase in epoxy content. Maximum elastic modulus is found to be 4.36 GPa for 15% epoxy content with 10% cast iron filler particles; hence, this material has very high stiffness values. Figure 3b shows the plot of tensile strength with respect to epoxy weight percentage in the presence of cast iron as filler material. From the nature of the curve, it is observed that better tensile strength values are attained for 5% inclusion of cast iron filler. The tensile stress of the specimens decreases with the increase in the content of cast iron filler particles in the composite specimens. The modulus of elasticity of the specimens increases with increment in the percentage of cast iron particulates. Hence, the specimens become stiffer with the increase in filler content. Maximum flexural strength of 42.3 MPa is obtained for specimen containing 50% epoxy content and with 5% addition of filler material.

The maximum compressive strength value obtained is 123 MPa for 25% of epoxy content with 10% filler material. Figure 4b shows the measured values of compression modulus of granite epoxy composite specimens with the presence of cast iron as filler particles. The modulus of elasticity is found to be higher for 10% of filler material. The elastic modulus of the specimens decreases with the increase in epoxy content. Maximum elastic modulus is found to be 4.36 GPa for 15% epoxy content with 10% cast iron filler particles; hence, this material has very high stiffness values.

Figure 3a shows the plot of tensile strength with respect to epoxy weight percentage in the presence of cast iron as filler material. From the nature of the curve, it is observed that better tensile strength values are attained for 5% inclusion of cast iron filler. The tensile stress of the specimens decreases with the increase in the content of cast iron filler particles in the composite specimens. The modulus of elasticity of the specimens increases with increment in the percentage of cast iron particulates. Hence, the specimens become stiffer with the increase in filler content. Figure 4 shows the characteristic curves of ultimate flexural strength as a function of epoxy percentage for specimens containing cast iron particles. From the nature of graph, it can be observed that the flexural strength of the fabricated composite specimens decreases with the increase in cast iron particulates. Maximum flexural strength of 42.3 MPa is obtained for specimen containing 50% epoxy content and with 5% addition of filler material.

4. DAMPING ANALYSIS

A graph of damping ratio plotted with respect to epoxy percentage for specimens without filler material is shown in Figure 4a. From the graph, it can be noticed that the damping value is found to be maximum at 0.034002 for specimen with 85:15 granite epoxy ratio. Minimum damping values are obtained for a granite epoxy ratio of 50:50 and thereafter it gradually increases. The damping ratio is higher for 5% cast iron filler. It further decreases with increase in filler content as shown in Figure 4b.

5. CONCLUSION

Granite epoxy composites exhibited highest damping for epoxy weight percentage between 10 and 20 and highest compressive strength of 112 MPa is observed at epoxy content of 30 wt%. The compressive strength increases with increase in filler content while tensile and flexural strength decreases with filler content. Inclusion of 5% cast iron particles as filler material for granite epoxy has resulted in improvement of damping factor for epoxy content >20 wt%. The cast iron as filler >5% resulted in the reduction of damping property. The damping factor decreased with increase in cast iron >5 wt%. Compressive strength increased with increase in cast iron content. However, tensile and flexural strength reduced with increase in cast iron fillers.

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***Bibliographical Sketch**

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