Effect of Moisture on Vibration Characteristics of SMA Particulate Reinforced Epoxy Matrix Composite

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Abstract—*Composite materials are being widely used in lot of applications with range from regular structural applications to naval applications. When using composites for naval applications, it is necessary to investigate the effect of moisture on the composite behaviour. Much research happened to study the effect of moisture on the strength characteristics of various composites, less investigation has been done to study the effect of moisture on vibration characteristics of composites. The current work aims at evaluating the effect of moisture and salinity on the vibration characteristics of SMA particulate Epoxy matrix composite as well as pure epoxy material. For this purpose, a test rig is fabricated and instrumented using IoT. ADXL345 sensor with Arduino is used for measuring vibrations. Excel is used for further data analysis. The experimental results are detailed in the paper.*

Keywords — *SMA particulate Epoxy Matrix Composite, ADXL345, Vibrations, moisture effect, Salinity effect*

I. INTRODUCTION

Composites are finding larger applications day by day and newer composites are being prepared. The main reasons behind such applications of composites is their strength to weight ratio and their vibration response characteristics.

A. Investigations into strength of SMA composites

SMA Composites, SMPs, SMEPs are finding a lot of applications in engineering applications [1]–[3], especially in the area of vibration damping. A detailed discussion of SMA self-healing coatings, their functioning methodology as well as their characterization was presented in [4]. Experiments performed by N. A. Smith, et al [5] indicated that there is a 100% increase in bonding strength if there saline agents are used to bind SMA wires with epoxy matrix. Jinsong leng, et al [6] discussed various aspects of shape memory polymers (SMPs), including fabrication, modelling and characterization of SMPs, SMP composites. Investigations summarized by Shicheng Zhao, et al [7] indicated that the SMA fiber and Epoxy material play a major role in determining the strength of SMA fiber reinforce GF Epoxy composite. G.B. Veeresh Kumar, et al [8] compared the experimental results Al6061-SiC and Al7075-Al_2O_3 composites. They found that Al6061-SiC exhibits superior mechanical and tribological properties.

B. Vibration Based Conditional Monitoring

Vibrations are largely used for conditional monitoring. Various techniques employed are reviewed in [9]. Techniques for using of vibrations so as to detect damage are discussed in [10], [11]. Cawley and Adams [12], [13] also used vibrations for damage detection in composite structures as well as determination of location of defects in the same. Use of vibrations for damage detection in laminates is presented in [14]. Gibson, et al [15], discussed the dynamic mechanical behaviour of composites by analytically and experimentally to predict the internal damping and the elastic stiffness of E-glass fibre-reinforced epoxy beams under flexural vibration. Maksim, et al [16], discussed the vibration damping and shock resistance of Nano composites. Jinsong leng, et al [17], performed experiments for monitoring the smart laminate composite by using EFPI and FBG sensors as well as by 3-point bending test. There are various ways of measuring vibrations. Vibration measurement is performed by various ways like using MFC Sensors [18], and accelerometers [9], [11], [14], [15], [19]. The use of IoT for low cost vibration measurement instrumentation is demonstrated in [20], [21]. R.Chandra, et al [22], reviewed the researches related to the damping in FRCs with polymer matrix material. Kin-tak lau, et al [23], has investigated the vibration response characteristics of SMA fiber reinforced composites.

C. Moisture Effects on Composites

Some researchers conducted experiments to find the effect of moisture on the composite material. Different composite materials namely, glass-epoxy and glass-polyurethane composite [24], [25], graphite reinforced composite [26], Jute Fiber Reinforced Polyester Composites [27], [28], Long Kenaf/Woven Glass Hybrid Composite [29], Sugar Palm Fiber reinforced Epoxy Composites [30], Saccharum cilliare fibre reinforced composites with resorcinol formaldehyde matrix [31], Hibiscus sabdariffa fibre reinforced urea–formaldehyde composite [32], Grewia optiva fiber reinforced Urea-Formaldehyde matrix composite [33], Pine needle reinforced resorcinol-formaldehyde composite [34] are tested in different moisture environments such as sea water, rain water, distilled water, etc. The tests include tensile, impact, flexural and impact. Some of them observed the effect of temperature also. Some of these examined morphologically by using SEM.

II. PROBLEM STATEMENT

Though moisture effects are investigated, most of the investigations included only strength characteristics. Its effect on vibration response has not been investigated. Thus, it is planned to investigate the vibration response of SMA particulate composite with epoxy matrix as well as on pure epoxy material when subjected to moisture and salinity. For these ten test cases are planned which are outlined in figure 1.

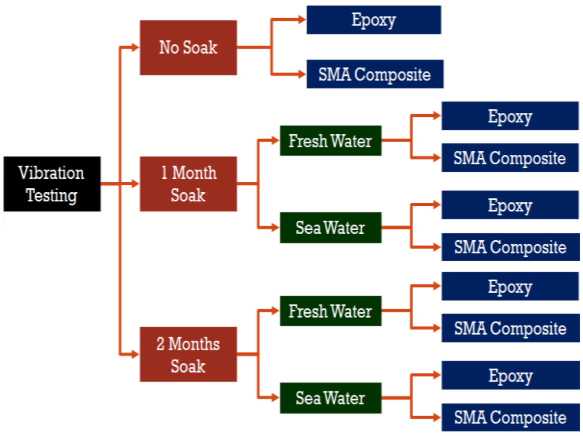

Fig. 1 Test Cases

III. SMA Particulate Composite

A composite with SMA particulates and Epoxy matrix is prepared by hand layup method. Various steps followed for composite preparation are given in figure 3. SMA Nano powder is mixed with Epoxy as 60% w/w. Plain epoxy plate as well as SMA particulate Epoxy Matrix composite plates are casted. Then samples of sizes 115mm X 19mm X 4mm are cut out of these plates. SEM of these prepared composites indicated that the SMA particles size in the prepared composite varied from 1μm to 14μm.

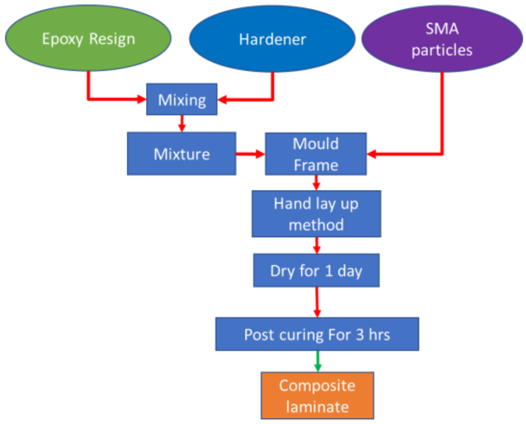

Fig. 2 Preparation steps of SMA particulate composite with Epoxy Matrix

IV. TEST RIG FABRICATION AND INSTRUMENTATION

For studying vibration response, the composite beams are fixed at one end and exited at the fixed end with varying frequencies. The frequencies of excitation are produced using two motors with eccentric masses. All these motors are beams are mounted on a wooden frame with the help of metal brackets. Vibrations are measured using ADXL345 accelerometer mounted at the end of the beam. This accelerometer is interfaced to the computer using Arduino. ADXL345 is calibrated using the procedure given in [35]. Complete experimental setup is shown in figure 3. The rpm of the motors is measured using optical tachometer.

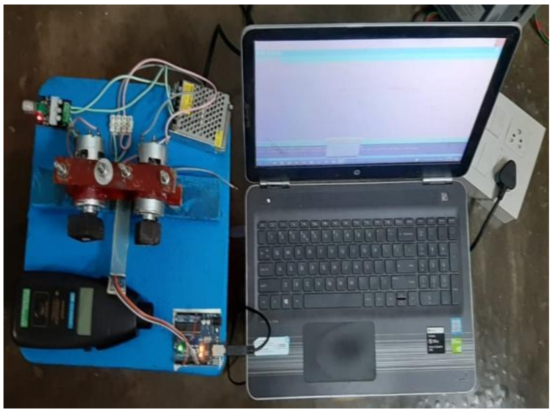

Fig. 3 Complete Experimental setup

V. Experimentation, Results and Discussions

As mentioned earlier, the vibration excitation is given using motors with eccentrics mounted on the motor. Vibration data is recorded using accelerometer which comes as output in serial monitor. Vibration data is recorded for 30 sec. Excel is used for further data analysis. Figure 4 shows the plot of vibration for 3 sec for dry SMA epoxy composite at 53.4Hz. The dry samples are soaked in Fresh water and Sea water and tests were conducted every month. The comparison of vibration response data is presented in figures 5 and 6.

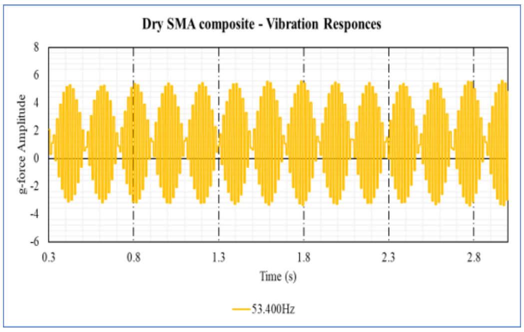

Fig. 4 Sample vibration response plot

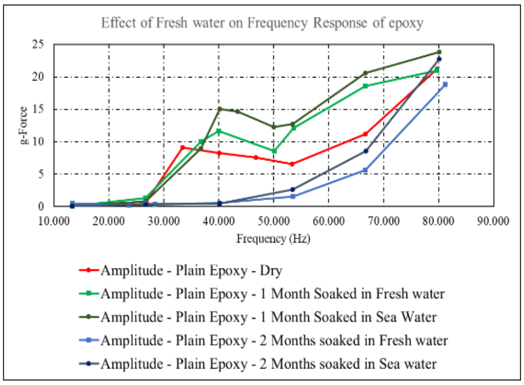

Fig. 5 Effect of moisture and salinity on pure Epoxy material

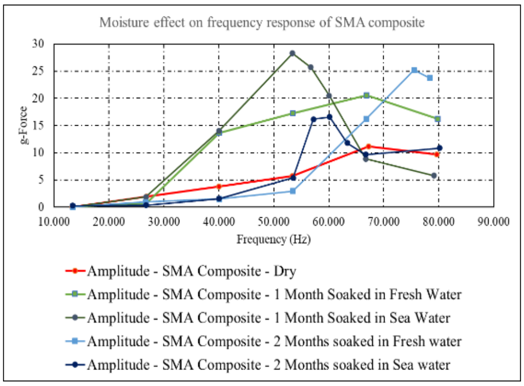

Fig. 6 Effect of moisture and salinity on SMA – Epoxy Composite

Based on these responses, the following inferences can be made:

1. As the moisture content is increasing in both pure epoxy as well as SMA composite, though the natural frequencies are increasing, higher amplitudes are observed at higher frequencies. This indicates that moisture has considerable effect on strength of the material.
2. Sea-water-soaked samples exhibited larger amplitudes when compared to that of fresh-water-soaked one. This indicates that salinity has larger effect on the composite than when compared with that of fresh water. For example, considering 1-month soak period, the peak amplitude with SMA-Epoxy composite at first natural frequency is around 20g for fresh water while for saline water it is around 28g. A similar effect is observed for epoxy material also.
3. SMA – Composite has higher natural frequency than that of epoxy material. In dry condition, the natural frequency of epoxy is 33.383 Hz while that of SMA-Epoxy composite is almost twice and is around 67.217 Hz. This can be attributed to the SMA particulates of the composite.

VI. CONCLUSIONS

Effect of moisture and salinity on vibration response of pure Epoxy material and SMA particulate Epoxy matrix composite are investigated. For this purpose, test rig with wooden chassis is fabricated. ADXL345 sensor with Arduino is used for vibration measurement. Experimental results indicated that:

1. Moisture has similar effect on both epoxy material as well as SMA particulate Epoxy composite.
2. SMA particulate Epoxy composite has higher natural frequencies than pure epoxy material
3. Larger amplitudes are observed for sample soaked in saline water
4. With increase in soaking time there is an increase in natural frequency of the material.

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