Evaluation of Mechanical Characterization of CFRP Reinforced Stainless Steel (SS304) Wire Mesh Polymer Composite

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Abstract

In recent days, fibre metal hybrid composites have been utilized for improve the stiffness, excellent corrosion resistance, low density and less weight. CFRP reinforced stainless steel (SS) wire mesh hybrid fibre metal laminate has been fabricated using hand layup process. Viscoelastic properties of fabricated composite samples have been studied by using Dynamic Mechanical Analysis (DMA) test. Mechanical characterization such as Dynamic Mechanical Analysis (DMA), Flexural test and tensile properties of the newly fabricated fibre metal laminated also investigated. The DMA parameters such as storage modulus (E'), loss modulus (E'"")(tan δ) has been investigated. Flexural test has been performed for evaluating the bending stress.DMA results revealed that storage modulus of E’ was maximum at 5 Hz. In this work tensile strength observed was 533.05 MPa at 16.19 KN. For Flexural strength obtained in the fabricated composite material was 1.03 KN.

Key words: Carbon fibre reinforced polymer, SS304 wire mesh, Epoxy Resin, DMA, Tensile, Flexural.

1. Introduction

Now a day’s composite materials has been used in many areas such as manufacturing industries, automotive and aircraft industries. The primary reason of this composite material was chosen because of less weight, relative stiffness and high strength. Recent years have seen valuable research work on and widespread applications of fiber-reinforced polymer (FRP) bars as flexural reinforcement for concrete structures. CFRP reinforced stainless steel (SS) composite has excellent fatigue resistance and can increase product lifespan by several times in many applications such as bullet proof jacket and body parts of a car that can be used [1]. Recent advancements in metal fibres have introduced a promising new type of stainless steel fibre with high stiffness, high failure strain, and a thickness which can be utilized in a steel fiber reinforced polymer. However, stainless steel is known to be susceptible to pitting corrosion [2].Composites offer many advantages when compared to metallic alloys, especially where high strength and stiffness to weigh ratio is concerned. Additionally, they provide excellent fatigue properties and corrosion resistance in applications [3].Mechanical behaviours of pure titanium, new titanium alloy films and CFRP/Ti alloy laminated composites are investigated in order to research of development of fibre metal laminates tanks for cryogenic rocket propellants [4].

While conventional fiber-reinforced polymer composites offer high strength and stiffness, they lack ductility and the ability to absorb energy before failure. This work investigates hybrid
fiber composites for structural applications comprised of polymer, steel fiber, and glass fibers to address this shortcoming. Varying volume fractions of thin, ductile steel fibers were introduced into glass fiber reinforced epoxy composites [5]. Impact of corrosion on mechanical properties of steel fiber reinforced composites was investigated. Corrosion of composite materials with plates of different types of stainless steel was compared. This work mentioned samples of steel reinforced polymer (SFRP) and four different types of stainless steel were subjected to 144 and 288 h of corrosion in ferric chloride solution [6]. GFRP spirals are also efficient in providing shear strength, laterally supporting compression and tension bars, and confining the compressive concrete core. In the tested specimens, CFRP bars were used as longitudinal reinforcement, whereas GFRP spirals were used for transverse reinforcement [7]. Tensile properties of a titanium-based fibre metal laminate have been investigated at quasi-static rates of strain. Initial attention focused on investigating the effect of varying the fibre orientation on the tensile modulus and strength of a range of carbon fibre/PEEK FMLs [8].

The influences of the processing parameters on the microstructure and mechanical properties of the stainless steel thin wall parts by laser direct deposition were investigated. The results show that the obtained microstructure of the stainless steel thin walls is all composed of directionally solidified dendrites under different processing parameters [9]. This work reports on a study in which the flexural strength and deformability of circular concrete members with hybrid reinforcement CFRP bars and GFRP spirals. Test results indicate that the CFRP-RC specimens failed gradually at a high degree of deformability before concrete crushing [10]. Applicability of using CFRP bars as longitudinal reinforcement in circular concrete columns was investigated. Their test results indicated that the CFRP reinforced and steel reinforced columns tested behaved similarly up to their peak loads. The CFRP bars were effective in resisting compression until after concrete crushing and contributed to column capacity [11]. This work revealed that, with the increasing of duration, corrosion potential of stainless steel after heat treatment shows fall followed by rise [12]. Heat treatment is used to enhance the mechanical properties of the material. DMA are used to elucidate Tg and some mechanical properties like strength, stiffness and damping behaviour of the material [13].

In this work stainless steel (SS 304) reinforced carbon fibre reinforced fibre metal laminate has been fabricated using hand layup process. Mechanical catheterization such as DMA, flexural and tensile test was evaluated.

2. Materials and Method

Carbon fibre, Stainless Steel (SS304) wire mesh, epoxy resin and hardener were used for preparing the fibre metal composite. In this experimental work 5-10 µm in diameter carbon fibre has been used (Figure 1). SS304 stainless steel wire mesh with 50 microns is used for this investigation is shown in Figure 2. Mechanical properties of SS-304 are shown in Table 1. CFRP/ SS-304 composite is a fibre metal laminate is composed of thin stainless steel layer is inter pressed with four layers of carbon fibre is bonded with epoxy resin [14]. In this way four layers were arranged until the required thickness is achieved. The unidirectional layers of carbon fibre aligned in different directions to suit predicted conditions. 30N loads were applied on the laminates for 24hours to form a composite material is shown in Figure 3. The mould is allowed to cure for about 2-3 days for better results and later remove the composite from the mould and proceed for trimming or cutting as per required dimensions according to ASTM standards. The CFRP/ SS fibre metal laminate composite was fabricated as per the Table 1 and is shown in Figure 3.
3. **Mechanical Characterization**

The mould is allowed to cure for about 2-3 days for better results and later remove the composite from the mould and proceed for trimming or cutting as per required dimensions according to ASTM standards.

3.1 Dynamic Mechanical Analysis (DMA)

DMA is used to study the visco elastic behavior of CFRP-SS304 with temperature. The sample is subjected by a controlled stress. The test samples were cut into Length – 53 mm, Width-10.2 mm and thickness- 2.3 mm as shown in Figure 4. The resultant sine wave response of the sample is measured using an LVDT sensor [15, 16]. The amplitude is used to calculate the storage modulus (E’). The phase lag is used to calculate the loss modulus (E’’). The damping factor tan δ = E’’/E’. In this investigation, fabricated composite is analysed under thermal and dynamic loading conditions using SEIKO DMAI-DMSC 6100. Dynamic Mechanical Analysis test was carried out.

Table 1 Mechanical Properties of SS 304 wire mesh

| Properties               | Value       |
|--------------------------|-------------|
| Compressive Strength     | 310 MPa     |
| Specific Heat            | 530 J/ Kg.K |
| Hardness                 | 2100 MPa    |
| Tensile Strength         | 620 MPa     |
| Young’s Modulus          | 203 GPa     |
| Melting Point            | 1723 K      |
| Thermal Conductivity     | 17 W/ m.K   |

![Figure 1 Carbon fibre used for this investigation](image1)

![Figure 2 SS-304 wire mesh](image2)

![Figure 3 Fabricated CFRP/SS-304](image3)
at nitrogen environment with a temperature range of 25-200°C at 2°C/min increment with various frequencies of 0.2 Hz, 0.5 Hz, 1 Hz, 2 Hz and 5 Hz under the tensile mode.

3.2 Tensile Testing
The CFRP/SS-304 composite is performed in Universal Testing Machine (UTM) to investigate tensile load. The specimen of this composite is shown in Figure 5. The Testing material has been performed in ASTM D 638 [17]. The dimension of this specimen is 30.37mm x 12.55 mm x 2.45 mm.

3.3 Flexural Test
This method is used to measure the bending stress of a CFRP/SS-304 composite material under three point loading condition. The test specimen used for this investigation is shown in Figure 6. The sample is fixed under two point loading condition. The sample is bent by the mandrel where force applied to the sample which is a third point loading in UTM machine.

4. Results and Discussion
4.1 Dynamic Mechanical Analysis (DMA)
4.1.1 Effect of temperature on Storage Modulus (E’) for different frequencies
The storage modulus E’ represents the stiffness of visco elastic behaviour of a sample material and it measure the stored energy during one loading cycle of the composite material CFRP/SS-304 of all frequencies. Figure7(a-e) explained the storage modulus of all frequencies 0.2 Hz, 0.5 Hz, 1 Hz, 2 Hz and 5 Hz.
Figure 7 shows the storage modulus (E’) obtained from the DMA. From the above figure, it was observed that the frequency 5 Hz has high storage modulus at 85.17327 °C at 1.46E+11 Pa [18]. It was identified that the CFRP/SS-304 composite has high storage modulus at frequency 5Hz. After that the material loses its viscoelastic behaviour among the other frequencies.
4.1.2. Effect of temperature on Loss Modulus (E’’) for different frequencies

The Loss Modulus E’’ represents the energy is dissipated during one loading cycle of the sample CFRP/SS-304 composite. Loss Modulus is decreases with increase in temperature by applying in the sample. Figure 8 (a-e) represents the results of loss modulus of all frequencies 0.2 Hz, 0.5 Hz, 1 Hz, 2 Hz and 5 Hz.

From the above figure 8, it was observed that frequency 0.5 Hz has high loss modulus (E’’) at 80.30649˚C at 3E+10 Pa. It was identified that the CFRP/SS-304 composite has high loss modulus at 0.5 Hz. After that it loses the energy dissipated during one loading cycle of the sample CFRP/SS-304 [19].

4.1.3. Effect of temperature on Loss Factor (tan δ)for different frequencies

The loss factor tan δ is the ratio of loss modulus to storage modulus. It represents the mechanical damping and internal friction in a viscoelastic system of a given sample CFRP/SS-304
composite. Figure 9 (a-e) represents the graphs results of loss factor of all frequencies 0.2 Hz, 0.5 Hz, 1 Hz, 2 Hz and 5 Hz were drawn.

![Graphs of tan δ for 0.2 Hz, 0.5 Hz, 1 Hz, 2 Hz, 5 Hz](image)

**Figure 9 Loss factor (tan δ)**

From the figure 9, it was observed that frequency 0.2 Hz has high loss factor (tanδ) at 78.07755 °C at 0.326386 loss factor [20]. It was identified that frequency 0.2 Hz has high loss factor compare to all other frequencies [22] of the given sample CFRP/SS-304 composite.

### 4.2 Tensile Test

The sample was test under Universal Testing Machine (UTM). While tensile test is applied to the sample, the grips are moves apart at a constant rate to pull and stretch the sample. The force of the sample and stroke is continuously monitored and plotted on stress-strain curve until sample failure or cracks are shown in Figure 10. The load displacement curve is plotted for determination of elastic modulus and ultimate tensile strength.
From figure 10, it was observed that the ultimate tensile strength of this sample CFRP/SS-304 composite is 533.05 MPa and maximum force where the sample breaks is 16.19 KN.

4.3 Flexural Test

The sample was tested for flexural strength under universal testing machine [21]. The results obtained in the form of graphical form from the UTM which is shown the Figure 11. During the bending stress, the change in the gauge section is recorded against the applied force.

From the Figure, it was observed that the flexural load of this sample CFRP/SS-304 composite is N. The flexural strength is maximum compare to other natural fibres. For Flexural strength obtained in the fabricated composite material was 1.03 KN.

5. Conclusions

Carbon fibre reinforced SS fibre metal laminate was fabricated using handlyup process. Mechanical characterization such as DMA, tensile and flexural has been evaluated. This research work revealed that addition of stainless steel mesh in the carbon fibre composite increased the tensile strength. From the experimental results the following conclusions has been drawn

- The stainless steel wire mesh in the carbon fibre composite increase the tensile strength up to 533.05 MPa
- By substitute the stainless steel mesh with carbon fibers on the compressive surface yields the maximum flexural strength.
- DMA results revealed that storage modulus (E’) obtained was maximum at 5 Hz

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