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STUDY OF MECHANICAL PROPERTIES ON GLASS FIBRE REINFORCED POLYMER MATRIX MATERIAL WITH SELF-HEALING AGENT

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ABSTRACT

One of the main problem in any materials is that after a brief period of time there will be some wear and tear due to friction or any chemical reactions taken place by the environmental factors or any extensive usage of material. This is common in any material, usually this wear and tear of the material leads to decreased functionality and productivity. Thus the materials are replaced with the new ones which will cost us. This paper briefly explains about development of new structural polymer material which has the characteristics of self-healing to increase its tensile strength when there is any occurrence of crack in the existing material, and stops further extension of crack. This behavior is inspired from the biological system where the self-healing is one of the basic characteristics. The following paper helps to develop a structural polymer which can lead to a new route toward safer, long-lasting, fault-tolerant products and components across wide areas of technology and industries including coatings, electronics, transportation, and energy.

Keywords: *Polyester Resin, Glass Fiber, Chlorobenzene, Self-Healing.*

I. INTRODUCTION

Composite materials are made up of two of more constituents which comprises of different physical and chemical properties. The composite materials have extensive usage in number of applications like computation, communication, reinforced plastics, fiber reinforced plastics, ceramics, metal composites etc. The mixing of high strength fiber with polymer matrix can greatly improve mechanical properties such as ultimate tensile strength, flexural modulus, and temperature resistance. The traditional method for repairing the composite materials is by adding any catalysts to the existing material to improve its static strength which can help the material to last longer than usual [1]. The concept of self-healing composites can be a way for overcoming the limits and extending the life expectancy while expanding their usage by using a catalyst urea formaldehyde micro capsules containing room temperature curing epoxy resin system (sc-15) as the healing agent prepared by in situ polymerization [2]. This bio inspired concept offers the designer an ability to incorporate secondary functional materials capable of counter acting service degradation whilst still achieving the primary, usually structural requirement. Most materials in the nature are themselves self-healing composite materials [3]. Self-healing materials are no more an illusion and we are not far away from the days when man made materials can restore the structural integrity in case of failures. The concept of self-repair has been discussed previously but the only successful crack healing methods that have been reported requires some form of manual intervention [4].

2. METHODOLOGY AND EXPERIMENTATION

A self-healing fiber reinforced structural polymer matrix composite material is demonstrated. The present work involves an experimental real-time setup which includes tensile testing of the composite specimen which involves polyester resin, glass fiber and a catalyst Chrolobenzene. The role of the reinforcement in a composite material is to increase its mechanical properties with suitable resin such as polyester. Polyester is a synthetic polymer. Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced-polymer (FRP). Chlorobenzene is an aromatic compound with the chemical formula C_6H_5Cl. This colorless, flammable liquid is a common solvent and a widely used intermediate in the manufacture of other chemicals

By adopting self-healing agent, the strength of the composite material can be increased. Thus in a way, it will be more strong and less prone to damage and failure. The life of the material can be extended with the addiction of particular agent.

Table 1: Physical properties of glass fiber

Properties	S-glass
Tensile Strength (Gpa)	4.6
Modulus (Gpa)	86.8
Elongation (%)	5.4
Density (g/cc)	2.46
Coefficient of Thermal Expansion ($10^7/^0c$)	23-27.0
Dielectric Constant RT, 10^{10} Hz	5.0-5.1

Table 2: Chemical properties of Chlorobenzene

Properties	Description
Chemical formula	C_6H_5Cl
Molar mass	112.56 g/mol
Appearance	colorless liquid
Odor	almond-like
Density	1.11 g/cm³, liquid
Melting point	−45 °C (−49 °F; 228 K)
Boiling point	131 °C (268 °F; 404 K)

Fabrication of specimen involves the preparation of composite material by hand layout technique. The tensile and bending specimen were fabricated according to ASTM D-3039 and ASTM D-790 respectively. The self-healing agent chlorobenzene is added to the polyester resin and a uniform mixing is achieved with the help of a blender. A comparative study for the below mentioned compositions of each constituents used are done.

Table 3: Composition of constituents

	Self healing agent %	Glass Fiber %	Polyester %
Case 1	0	20	80
Case 2	1	20	79
Case 3	5	20	75

The Tensile and bending tests were carried out in Universal Testing Machine. The test was carried out for three different cases mentioned in table 3. The peak load was found from the test.

Results and Discussion:

The below graphs were obtained after conducting tensile test for the specimens under predefined load value

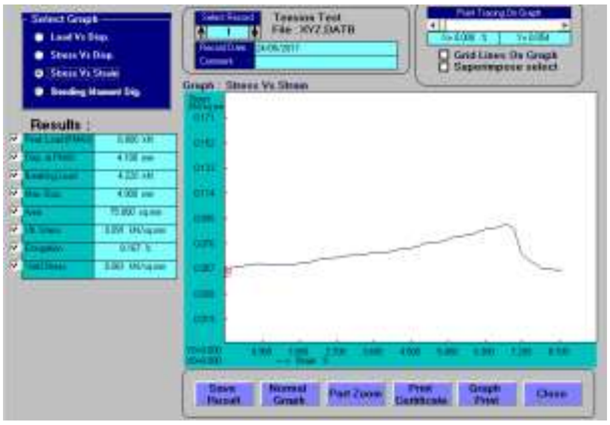

Fig 1: stress v/s strain diagram for tensile test for case 1

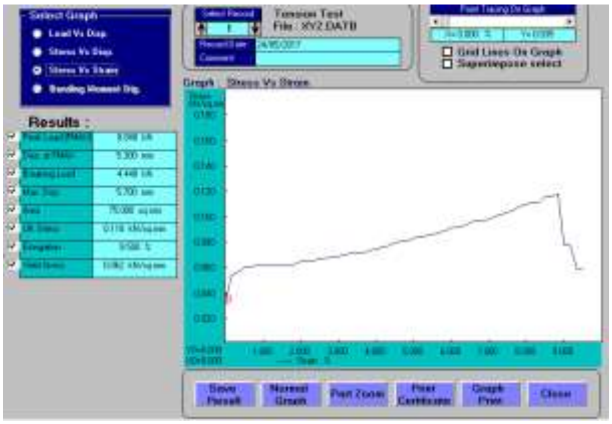

Fig 2: stress vs strain diagram for case 2

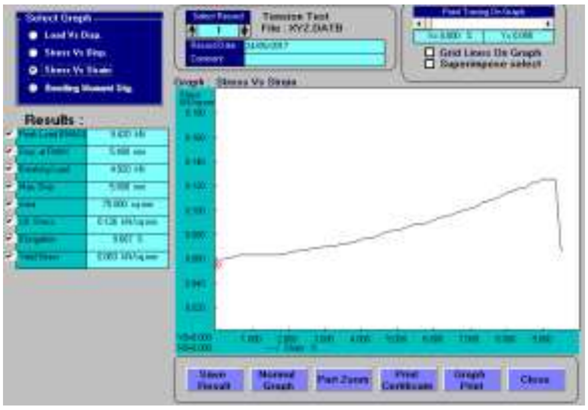

Fig 3: stress v/s strain diagram for tensile test

Table 4: comparison of tensile results

Parameters	Case 1	Case 2	Case 3
Peak load (FMAX)	6.800 kN	8.840 kN	9.420 kN
Disp of FMAX	4.100 mm	5.300 mm	5.400 mm
Breaking Load	4.220 kN	4.400 kN	4.920 kN
Max disp	4.900 mm	5.700 mm	5.800 mm
Area	75.000sq mm	75.000 sq mm	75.000 sq mm
Elongation	8.167 %	9.500 %	9.667 %
Yield stress	0.061 kN/sq mm	0.062 kN/sq mm	0.063 kN/sq mm

The three cases were tested and the resultant graphs and tabular columns are obtained. To know the absolute strength in each case, the peak load values of each case has been taken as shown below

Case 1: Tensile load for 20% glass fiber + 80% polyester

Maximum load for specimen1 (P max) = 6.8kN = 6800 N

Case 2: Tensile load for 20% glass fiber + 1% self healing agent+79% polyester

Maximum load for specimen1 (P max) = 8.840kN = 8840 N

Case 3: Tensile load for 20% glass fiber + 5% self-healing agent+75% polyester

Maximum load for specimen1 (P max) = 9.420kN = 9420 N

$$\text{Tensile strength } (\sigma_t) = \frac{\text{Load at failure (P max)}}{\text{cross-sectional area (A)}} \text{ MPa}$$

The tensile strength in each case is found using the above formula

The results of bending results are depicted below in the figures.

Fig 4: bending test results for case 1

Fig 5: bending test results for case 2

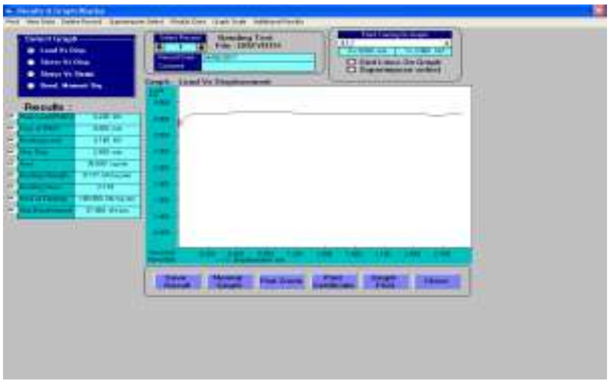

Fig 6: bending test results for case 2

Table 5: bending results comparison

Peak Load (FMAX)	4.220 kN	4.440 kN	4.400 kN
Disp of FMAX	0.800 mm	2.700 mm	2.900mm
Breaking Load	4.140 mm	4.260 k N	4.240 k N
Max Disp	2.900 mm	4.800 mm	4.500 k N
Area	36.000 sq mm	36.000 sq mm	36.000 sq mm
Bending strength	0.117 k N / sq mm	0.123 k N / sq mm	0.122 k N/sq mm
Bending stress	2110	2.220	2.200
Mod of Elasticity	189.900 k N/ sq mm	59.200 k N/sq mm	54.621 k N/sq mm
Max Bending Moment	37.980 k N mm	39.960 kN mm	39.600 k N / mm

Flexural strength = $3PL/BD^2$

Maximum load for case 1 (P max) = 4.400 kN = 4400 N
Maximum load for case 2 (P max) = 4.40 kN = 4500 N
Maximum load for case 3 (P max) = 4.40 kN = 4360 N

The bending strength for case 1=3.940 kN/mm^2
The bending strength for case 2=4.078 kN/mm^2
The bending strength for case 3=4.014 kN/mm^2

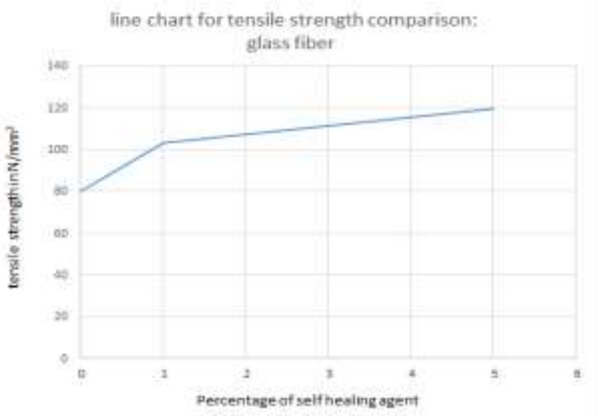

Fig 7: line chart for bending strength comparison

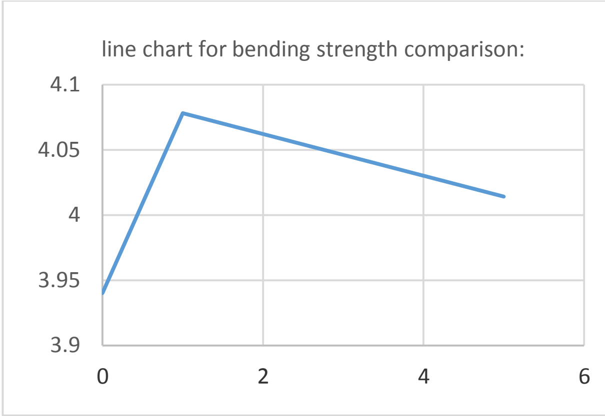

Fig8 : line chart for bending strength comparison

Table 6: Comparison of tensile and bending strength

	% of self-healing	Tensile strength in N/mm^2	Bending strength in kN/mm^2
Case 1	0	79.733	3.940
Case 2	1	102.933	4.078
Case 3	5	119.2	4.014

It is observed that the case 3: 20% glass fiber + 5% self-healing agent+75% polyester has higher tensile strength compared to the other two cases. The tensile strength is increasing with the increase in composition of self healing agent. Whereas it is observed that the case 2: 20% glass fiber + 5% self-healing agent+75% polyester has the higher bending strength compared to the other two cases. Therefore it is recommended to use the case 3 compositision where the tensile strength is considered and the case2 composition wherever bending strength should be considered.

To analyze the uniform distribution of the prepared composites scanning electron microscope (SEM) test has been carried out for case 2 and case 3. Both the surface before and after fracture has been analysed. The results are depicted in the figures below.

Case 2: 1% self healing agent 20% glass fiber 79% polyester

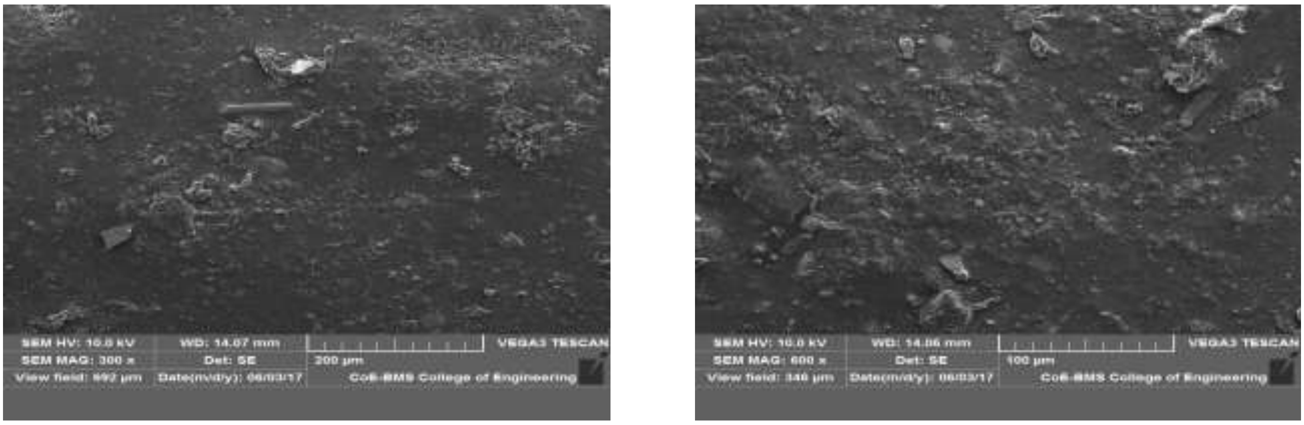

Fig 9: the surface before fracture

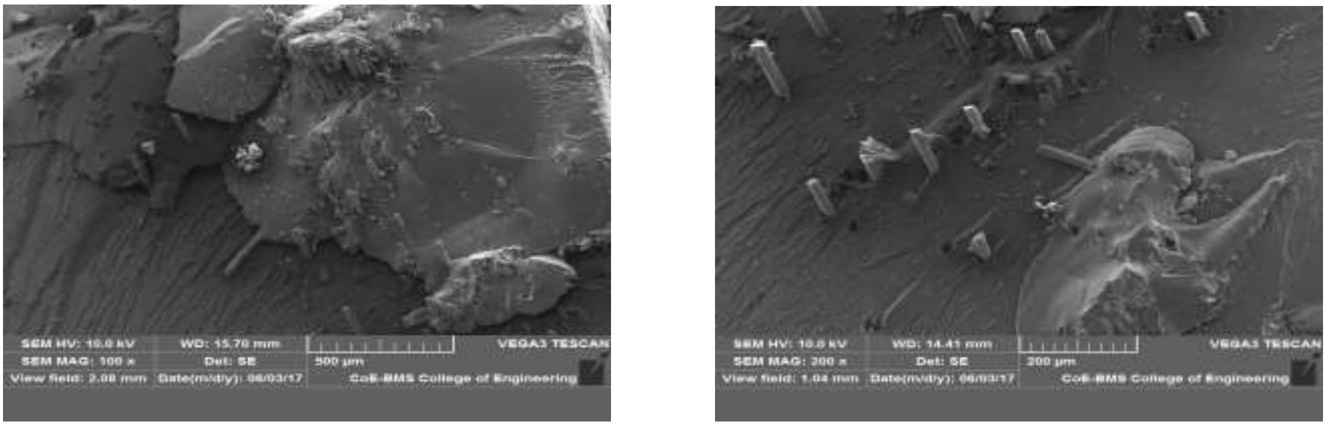

Fig 10: the surface after fracture

Case 3: 5% self healing agent 20% glass fiber 75% Polyester

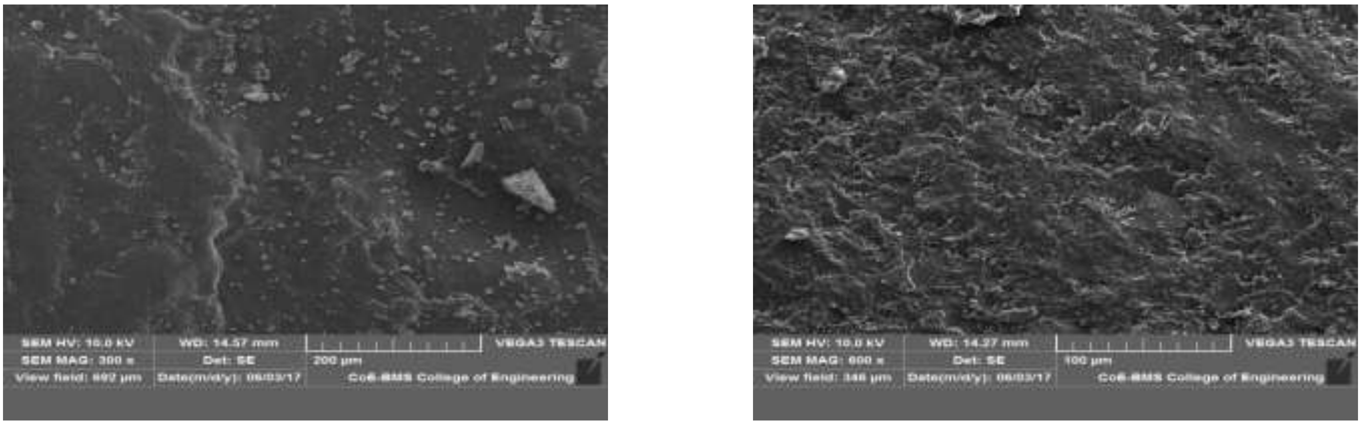

Fig 11: the surface before fracture

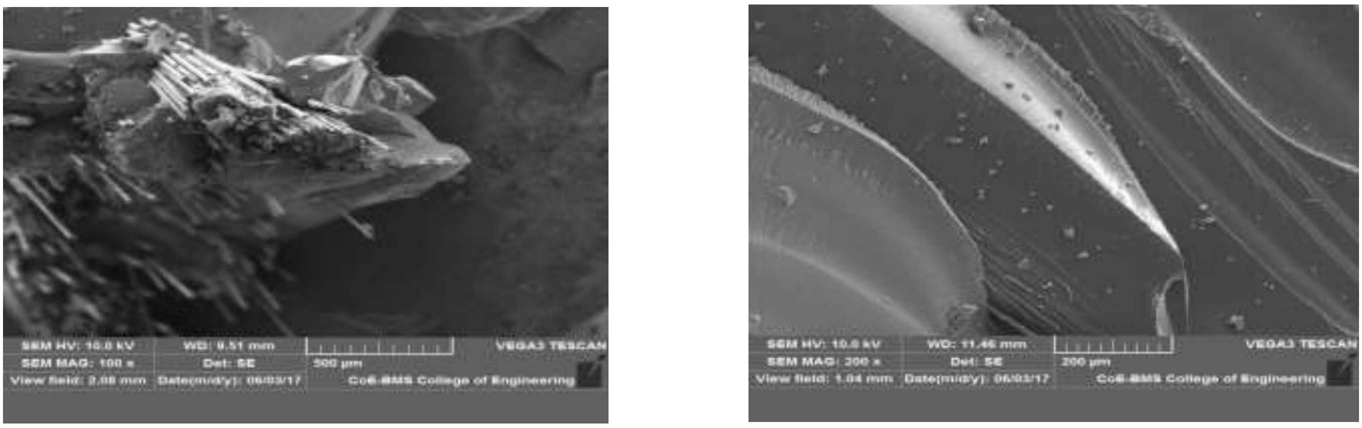

Fig 12: the surface after fracture

It is evident from the SEM analysis that the particles are holding together the fibers preventing them from failure. A more uniform distribution is seen in case 3, where more amount of chlorobenzene is added.

4. CONCLUSION

It is observed from the tensile test that the use of self -healing agent like chlorobenzene can increase the strength of the composite specimen. In case of bending strength, the usage of chlorobenzene upto 1 % increased the bending strength. Also a uniform distribution of the particles are visible in SEM test. It is observed that the chlorobenzene particles holds the fibers together making it strong and less vulnerable to failure. Hence in order to increase the life period of a structure, it is recommended to use chlorobenzene.

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