

Influence of Aviation Fuel on Mechanical properties of Glass Fiber-Reinforced Plastic Composite

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Abstract: Glass fiber reinforced plastic (GFRP) composites are one of the most widely used composite materials, as they have good balance between properties and costs. GFRP laminate composite widely use in aircraft industry to produces the aircraft main bodies, doors, ailerons, spoilers and other aircraft components. During their in-service life, These composite materials can expose to different working condition as well as to different environments, where Moisture can be introduced to the materials; in such working condition the properties of such materials needs to be well understood for appropriate design and use. The focus of this research is to determine the effect of aviation fuel on the glass fiber reinforcement plastic. Therefore, the GFRP specimens were manufacture by vacuum infusion process and the specimens were subjected to aviation fuel immersion tests, using AVGAS 100LL and ATF, in order to study the effects of oil absorption behaviour on flexural properties of GFRP composites. Both solutions affect the flexural properties. However, for tests performed, the ATF promotes the highest effect on the flexural properties.

Keywords: GFRP, Composite materials, Aircraft, AVGAS and ATF.

I. INTRODUCTION

Composite Materials

A typical composite material is a system of materials composing of two or more materials (mixed and bonded) on a macroscopic scale. For example, concrete is made up of cement, sand, stones, and water. If the composition occurs on a microscopic scale (molecular level), the new material is then called an alloy for metals or a polymer for plastics. Generally, a composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material.

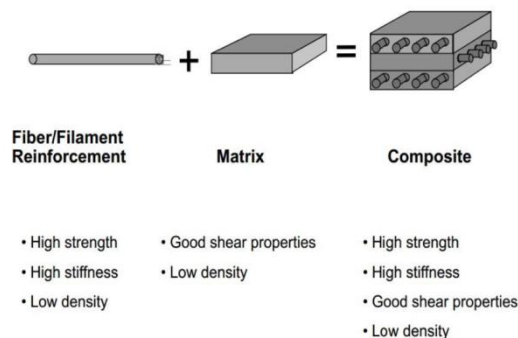


Figure 1- Composition of Composite

Composition of Fiber Reinforced Composites

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while the matrix 'glues' all the

fibers together in shape and transfers stresses between the reinforcing fibers. Sometimes, fillers or modifiers might be add to smooth manufacturing process, impart special properties, and/or reduce product cost.

Matrix of Fiber Reinforced Composites

The primary functions of the matrix are to transfer stresses between the reinforcing fibers (hold fibers together) and protect the fibers from mechanical and/or environmental damages. A basic requirement for a matrix material is that its strain at break must be larger than the fibers it is holding. Most matrices are made of resins for their wide variation in properties and relatively low cost. Common resin materials include

- Resin Matrix
 - Epoxy
 - Phenolic
 - Polyester
 - Polyurethane
 - Vinyl Ester

Among these resin materials, polyesters are the most widely used. Epoxies, which have higher adhesion and less shrinkage than polyesters, come in second for their higher costs.

Glass Fiber-Reinforced Plastic (GFRP)

There are three main types of synthetic fibers are used widely to reinforced plastic materials: glass, aramid, and carbon. Glass is by far the most widely used reinforcement fiber and is the lowest in cost. Aramid and carbon fibers have high strengths and low densities and so are used in many applications, particularly aerospace, in spite of their higher cost.

Glass fibers are used to reinforce plastic matrices to form structural composites and molding compounds. Glass-fiber plastic composite materials have the following favorable characteristic:

- High strength-to-weight ratio
- Good dimensional stability
- Good resistance to heat, cold, moisture, and corrosion
- Good electrical insulation properties
- Ease of fabrication
- Relatively low cost.

There are two most important types of glass used to produce glass fibers for composites are E (electrical) and S (high-strength) glasses. E-glass is the most commonly used glass for continuous fibers. Basically, E-glass is highly electrically resistive glass made with lime-aluminum-borosilicate glass with zero or low sodium and potassium levels. E-glass is known in the industry as a general purpose fiber for its strength and electrical resistance. It is the most commonly used fiber in the fiber reinforced polymer composite industry. S-glass has a higher strength-to-weight ratio and is more expensive than E-glass and is used primarily for military and aerospace application. It is made with magnesium aluminosilicates. Used where high strength, high stiffness, extreme temperature resistance, and corrosive resistance is needed.

Table 1-General Properties of E-Glass and S-Glass

	E glass	S glass
Composition	52 to 56 percent SiO ₂ 12 to 16 percent Al ₂ O ₃ 16 to 25 percent CaO 8 to 13 percent B ₂ O ₃	65 percent SiO ₂ 25 percent Al ₂ O ₃ 10 percent MgO
Tensile Strength	3.44 GPa	4.48 GPa
Compressive strength	1.080 GPa	1.600 GPa
Modulus of Elasticity	72 GPa	89 GPa
Density (g/cm ³)	2.54	2.53
Softening T (°C)	846	1056

GFRP Properties

Below is a mechanical and physical property, which had been obtained by other researcher. The specimen used in that experiment is the unidirectional E glass reinforced plastic. From the table, the theoretical value for max tensile strength as per ASTM D3039 is 152 KSI while the tensile Modulus of Elasticity is 6.0 MSI

Table 2-Unidirectional E-glass Mechanical and Physical Properties

PROPERTY DESCRIPTION (ORIENTATION AND MATERIAL CONSTANT)	UNITS	TEST METHOD	MIN. VALUE	MAX. VALUE
Product Type		ASTM D3647	Unidirectional	
Glass Content by Weight	%	ASTM D2584	68	70
Density	lbs./c.i.	ASTM D1505	0.068	0.068
Fiber Orientation	0/90 deg.	ASTM D3647		
Flex Strength	KSI	ASTM D790	184	210
Flex Modulus	MSI	ASTM D790	5.6	6.3
Tensile Strength	KSI	ASTM D3039	130	152
Tensile Modulus of Elasticity	MSI	ASTM D3039	5.6	6.0

Poisson's Ratio 0/90 deg. tension		ASTM D3039		0.29
Compression Strength, 0 deg.	KSI	ASTM D3410	77.7	111
Compression Modulus of Elasticity, 0 deg.	MSI	ASTM D3410	5.46	6.0
Compression Strength, 0 deg.	KSI	ASTM D3410	77.7	111
Compression Modulus of Elasticity, 0 deg.	MSI	ASTM D3410	5.46	6.0
Ultimate Compression Strain, 0 deg.	%	ASTM D3410	1.4	1.9
Compression Strength, 90 deg.	KSI	ASTM D3410	20.6	21.2
Compression Modulus of Elasticity, 90 deg.	MSI	ASTM D3410	1.5	1.8
Poisson's Ratio, 0 deg. compression		ASTM D3410		.29
In Plane Shear Strength	KSI	ASTM D5379	6.29	7.4
In Plane Shear Modulus	MSI	ASTM D5379	.5	.65
In Plane Shear Strength	KSI	ASTM D5379	3.6	4.9
In Plane Shear Modulus	MSI	ASTM D5379	.4	.49
Water Absorption	%	ASTM D570		.04
Glass Transition Temperature	deg. F	ASTM D3418	240	250

note: Strength values developed from ASTM D790 are dependent on thickness.

*Source from

http://www.rbsbattens.com/tech/physical_prop.cfm

Motivation

Nowadays, composite materials are used in several engineering applications, as a consequence of their high specific strength and stiffness, competitive cost, good static and dynamic properties, good resistance to corrosion and simplified fabrication. In their service life these composite materials are exposed at different environment conditions, which affect significantly their mechanical properties. In terms of moisture, irreversible material degradation occurs and some chemical changes can be found (relaxation and oxidation of the matrix material), fiber/matrix debonding and continuous cracks. When the water penetrates into the matrix, by diffusion or by the interface fiber/resin of a composite, it acts as a plasticizer and decreases significantly the glass-transition temperature. This phenomenon makes composites softer, since the matrix becomes pliable due to the presence of the plasticizer. However, the rate at which water is absorbed depends on many factors, including the properties of fibers and matrix, temperature, differences of water concentration within the composite and the environment.

Objective

To determine the Flexure properties of the GFRP laminate composite after submerging it into AVGAS 100LL and ATF.

II. LITERATURE REVIEW

Guina Ren, Xiaotao Zhu, Xuehu Men, Zhaozhu Zhang, Fang Guo, Mingming Yang and Weimin Liu (2016) Nomex fabric/phenolic composites were soaked in aviation hydraulic fluid for 24 h, and their corresponding mechanical and tribological properties were investigated. Tensile and bonding strength test, Friction and wear test were conducted. It was found that the mechanical property of the oil-fouled Nomex fabric/phenolic composites decreased compared to that of untreated fabric composite. Moreover, sliding wear tests indicated that the lubricating effect of aviation hydraulic fluid and jet fuel oil improved the tribological property.

Mortas N, Erb O, Reis PNB and Ferreira JAM (2014) The corrosive environment decreases the impact strength and its effect is highly dependent of the concentrations of solution. Finally, independently of the nature of aggressive

solutions and of their concentration, the fact is that if composites are exposed to acid solutions at higher temperatures, the exposure induces a decreasing of the mechanical properties.

Amaro AM, Reis PNB, Neto MA and Louro C. (2013) compared the effects of alkaline and acid solutions on glass/epoxy composites. Authors showed that the alkaline solution is more aggressive than the acid solution, promoting the lowest flexural properties. In terms of acid solutions, for example, the hydrochloric acid is responsible by the worst results. The ultra micro indentation showed a decreasing of the matrix mechanical properties and the roughness was higher for the samples immersed in alkaline solutions.

Reis PNB, Ferreira JAM, Costa JDM and Santos MJ (2012) Fatigue performance of Kevlar/epoxy composites with filled matrix by cork powder tendency was observed, on Kevlar/epoxy composites, in which significant decreases of static and fatigue strengths were reported. However, when the water is combined with the temperature, it is possible to observe that all properties referred above decreases significantly.

Stamenovic M, Putic S, Rakin M, Medjo B and Cikara D (2011) studied the effect of alkaline and acid solutions on the tensile properties of glass-polyester composites. They concluded that the alkaline solution decreases the tensile properties (ultimate tensile strength and modulus) and this tendency increases with the pH value. Concerning the acid solutions, they increase the tensile properties and this tendency was more relevant when the pH value decreases. For both solutions, Stamenovic M. concluded that the changes observed on the tensile properties are proportional with the exposure time (number of days in liquid).

Banna MH, Shirokoff J and Molgaard J. (2011) Some studies about the effect of alkaline and acid solutions on composite materials can also be found in their paper. According to them the final mechanical properties of composite materials subjected to aggressive solutions is determined by the type of resin used. They also showed that in expositions to higher temperature solutions or to higher exposure duration, the polyester resin has lower modulus values than the bisphenol A epoxy vinyl ester resin. However, in both resins, the average hardness increases after 2 weeks of exposition and, then, decreases after 4 weeks exposure (but still higher than the unexposed). Finally, they have concluded that under acid and higher temperature exposures, the microstructure of polyester material degrades more rapidly than the microstructure of bisphenol A epoxy vinyl ester resin, which can be justified by the increased surface roughness, cracks and diffusion of sulphur into the cracks.

Sindhu K, Joseph K, Joseph JM and Mathew TV (2007) Degradation studies were carried out in different solvents like 10% NaOH, 1 NHCl and 10% NaCl and its influence on mechanical properties was analysed. It was observed that the tensile strength and the modulus (E) increases in acid environments and decreases for the other solvents. Finally, several studies were performed on GRP under stress corrosion cracking conditions.

Kawada H and Srivastava VK. (2001) According to Kawada and Srivastava stress corrosion cracking in GRP occurs as a result of a combination of loads and exposure to a corrosive environment. Sharp cracks initiate and propagate through the material as a direct consequence of the weakening of the glass fibers by the acid. The strength of the fiber reduces dramatically as a result of diffusion of acid and chemical attack of the fiber surface at the crack tip, which causes a highly planar fracture with a much reduced failure stress.

III. SPECIMENS PREPARATION

The method that is used in the present work for manufacturing the laminated composite plates is Vacuum Infusion. The required equipment and methodology is explained further in this chapter. At last it shows the specimens submerged into different aviation fuels.

Raw material

The following materials are used for the fabrication of GFRP Composites.

- ❖ Glass Fibers such as Woven Roving (WR)
- ❖ Resin
- ❖ Hardener
- ❖ Glass fiber (Woven roving mat)

Fiberglass Types

Fiberglass materials are available with a variety of compositions. This allows for additional design flexibility to meet performance criteria. The glass fibers used here is types "E".

Fiber glass Reinforcement Forms

Woven roving-Woven roving provides high strength to large molded parts and is lower in cost than conventional woven fabrics.(Thicknesses-0.2mm).

Reinforcement Arrangement

Unidirectional

The glass fiber mat was cut in 30*30cm² for lamination. Of 30*30cm² size fifteen pieces were cut for fifteen layers.

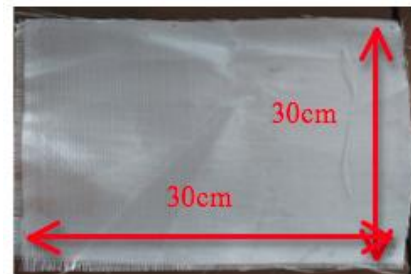


Figure 3- 30*30cm² mat

❖ Resin

The second major component of fiberglass is the resin system. The thermosetting resins used in fiberglass fall into two general categories polyesters and epoxies. Epoxyresins, also known as poly epoxides are a class of reactive prepolymers and polymers, which contain epoxide

groups. A wide range of epoxy resins is produced industrially. The raw materials for epoxy resin production are today largely petroleum derived. Hardener forms a thermo setting polymer, often with high mechanical properties, temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics/electrical components, high-tension electrical insulators, fiber-reinforced plastic materials, and structural adhesives etc.

Epoxy resins selected for this project is Araldite® GY 257. Araldite® GY 257 is a low viscose epoxy resin based on Bisphenol A modified with an aromatic glycidyl ether. Araldite® GY 257 can be cured with polyamines, polyamidoamines or their adducts for solvent-free coatings, self-leveling and mortar floors, concrete injections, structure adhesives, trowelling compounds and impregnation systems.

Due to the low viscosity and the full crystallization resistance Araldite® GY 257 is a most suitable epoxy resin in formulating solvent free systems yielding,

- Very good processing properties
- Good mechanical performances
- Good surface penetration
- Medium chemical resistance / good acid and solvent resistance

Table 3- Key data of Araldite® GY 257

Property	Value	Test method
Appearance	Clear, no contamination	JCTM 001
Epoxy value	5.20 – 5.50 eq/Kg	ASTM D-1652
Weight per epoxide	180 – 192 g/eq	ASTM D-1652
Viscosity at 25 °C	500 – 700 mPa.s	ISO 12058-1
Density at 25°C	1.15 g/cm ³	ISO 1675
Flash point	≥ 138 °C	ISO 2719

❖ Hardener

Hardener is high viscous liquid material, mixed with resin in suitable proportion during the process of preparation of composites, which helps in the solidification of the wet, smooth composite. It is used to harden the smooth composite hence it is called as hardener. In this project a Aradur® 2963 hardener is used. Which is Very low viscosity, formulated light-coloured hardener for self-leveling floorings and mortar (phenol-free).

Table 4- Key data of Aradur® 2963

Viscosity at 25°C [mPa s]	Amine value [mg KOH/g]	H+ Equivalence [g/Eq]	Typical mix ratio[g/100g GY 257]
30-70	325-350	85	45

Vacuum infusion, also called resin infusion, is a fabrication technique that uses vacuum pressure to drive resin into a laminate. Dry materials are laid into the mold and the vacuum pressure is applied before resin is introduced. Once a complete vacuum is achieved, resin is forced into the laminate via vacuum tubing. In a typical hand lay-up, reinforcements are laid into a mold and manually wet out using brushes, rollers, or through other means. An improvement on that method is to use a vacuum bag to suck excess resin out of the laminate.

Benefits of VIP

- Higher fiber-to-resin ratio(up to 70% fibers by weight)
- Higher strength and stiffness
- No resin entrapped air/very low voids
- Very consistent laminate with great process control (less human errors)

Vacuum infusion process

Before we Start we must understand Once the epoxy infusion resin has been mixed with its hardener, if anything goes wrong it is generally too late to do anything about it. Any problems such as running out of resin, loosing vacuum or having a leak in the bag will almost certainly result in the part being ruined. This means that for the first few attempts, methodical planning is essential. Having said this, the nature of resin infusion is such that correctly following the procedure should produce perfect parts every time. Figure 4 illustrates the vacuum infusion principle and the basic equipment. The dry reinforcement is placed on a flat table and is subsequently covered with a peel ply, Infusion flow media and finally with vacuum bag film, which is sealed at the edges with the help of sealant tape leaving room for the resin inlet and outlet. During infusion the resin flows from inlet, through the fiber reinforcement and subsequently the outlet.

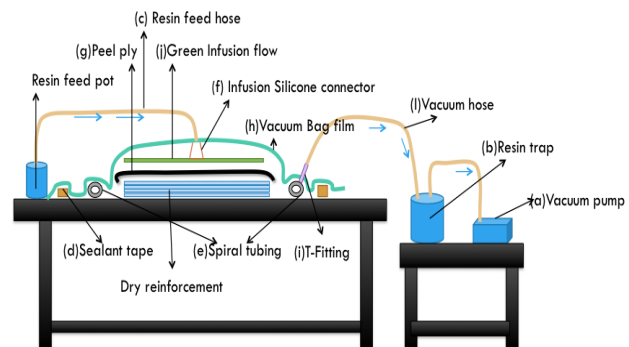


Figure 4-Schematic overview of vacuum infusion process



Figure 5-Original setup of vacuum infusion process Cutting of test specimens

After preparation of glass fiber laminate, according to ASTM D790-10, standards required test specimens are prepared by cutting operation. Water jet cutting machine were used for cutting of the Specimens. Length of the specimens is 250mm and the nominal thickness was 3mm, while the width is maintained at 25mm. The specimen and left out scrap sheets are shown in the below figure 6.

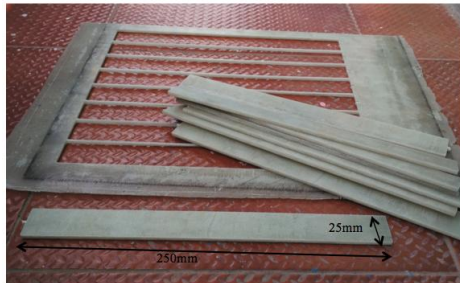


Figure 6- Specimens and left out scrap

The ASTM specifications allow a wide freedom of choice in terms of specimen dimensions, as long as the cross-section is rectangular and specific span to thickness ratio (s/h) ratios (16:1, 32:1, 40:1 and 60:1) in three-point bending.

Table 5-Dimensional possibilities for flexure specimens Specification

Specification	Thickness (mm)	Width (mm)	Length (mm)
ASTM D790-M	1-25	10-25	50-1800

Submerging the specimens

Finally, after doing above things the six specimens were completely submerged into two types of aviation fuel three specimens in each, Avgas 100LL (blue) and ATF (clear to straw-colored). The specimens were submerged into room temperature and the exposure durations were 15 days. An important remark is the fact that both faces of the specimens were exposed to the aviation fuels, what it is not very typical in real conditions. Afterwards, they were cleaned with tissue paper.

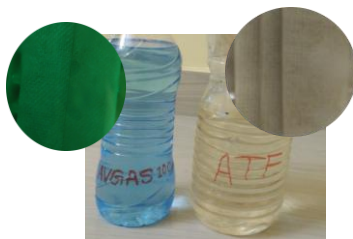


Figure 7- Specimens submerged into aviation fuels

TESTING AND RESULT

Based on BS EN ISO 62:1999 standard, the following procedure was used to obtain the fuel absorption: the samples were placed in room temperature for 12 h, then weighed in order to obtain the dry weight (DW); afterwards, a series of samples were immersed in the respective fuels (AVG and ATF) and, periodically, weighted to obtain the current wet weight (CWW). The

fuel absorption, in weight percentage (W%), was calculated using Eq. (1):

$$W\% = \frac{CWW - DW}{DW} \times 100\% \tag{1}$$

Table 6- Fuel absorption

	Fuel absorption (%)		
	Specimen 1	Specimen 2	Specimen 3
AVG	0.06	0.15	0.24
ATF	2.11	2.01	1.14

Specimens Original, AVGAS 100LL and ATF were named as specimen respectively Orig, AVG and ATF and were subjected to a 3 point Flexural/Bending Test in FSA M-100 UTM available in Hindustan University according to ASTM D790-10. UTM is shown in figure 8 below. The testing machine is equipped with a 100 kN load cell and WINUTM software. The test was performed at a displacement rate of 5 mm/min. All tests were also carried out at room temperature, with a span length of 82 mm. 3 specimens were used for each test. The load was applied up to the point of fracture and the parameters such as flexural strength, flexural modulus, and maximum load at the point of fracture for each specimen was obtained from the machine were recorded. All the data obtained during experimentation and simulation are recorded and tabulated in Table 7.

Bending strength was calculated as the nominal stress at middle span section obtained using maximum value of the load. The nominal bending stress was calculated using Eq. (2):

$$\sigma = 3pL / [2bd]^2 \tag{2}$$

where P is the load, L is the span length, b is the width and h is the thickness of the specimen. The stiffness modulus was calculated by the linear elastic bending beams theory relationship Eq. (3):

$$E = [\Delta P.L]^3 / (48\Delta U.I) \tag{3}$$

where I is the moment of inertia of the cross-section and ΔP, ΔU are, respectively, the load range and the flexural displacement range at middle span for an interval in the linear region of the load versus displacement plot. The stiffness modulus was obtained by linear regression of the load–displacement curves considering the interval in the linear segment with a correlation factor greater than 95%.

The result obtain from machine was verify theoretically by the equation (2). UTM and mathematically result is presented below. Mathematically result is shown below for Flexural stress, which is derived from the equation (2).

$$\begin{aligned} \sigma &= 3pL / [2bd]^2 \\ p &= 0.071 \text{ kN } \square 71\text{N} \\ L &= 82\text{mm}, b=25\text{mm}, d=3\text{mm} \\ &= \frac{3 \cdot 71 \cdot 82}{2 \cdot 25 \cdot 3^2} \Rightarrow \frac{17466}{450} \\ &= 38.813 \text{ N/mm}^2 \end{aligned}$$

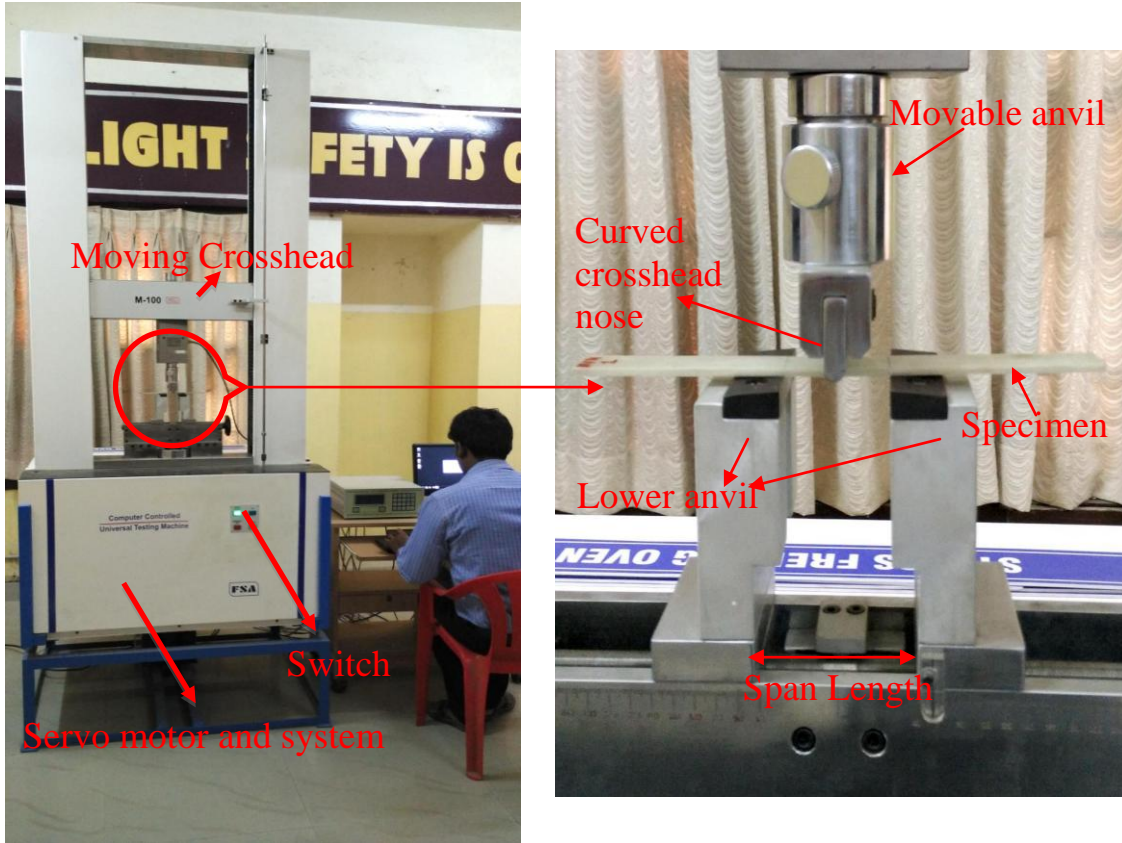


Figure 8- FSA Universal testing machine

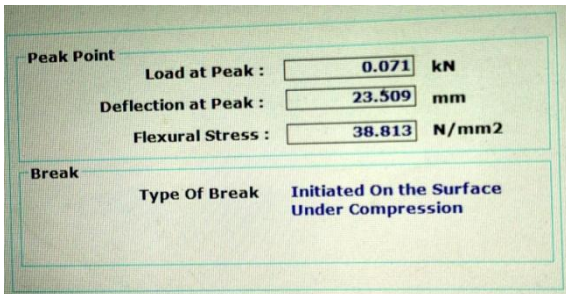


Figure 9-Result for AVG (specimen 3) from UTM

As we can see the result match exactly as the result from UTM software. The standard deviation (estimated) was calculated as follows, the formula is as ASTM D790 – 10 standards.

$$S = \sqrt{(\sum X^2 + n\bar{X}^2) / (n-1)} \quad (4)$$

where:

- s = estimated standard deviation,
- X = value of single observation,
- n = number of observations, and
- \bar{X} = arithmetic mean of the set of observations

Flexural parameters of laminated Composites were tested and results tabulated for various combinations of fiber system as per tests recommended by ASTM standards.

The result obtain from the win software were later mathematically calculated to match the result with software. The values obtained have been analyzed from

available literature & an agreement between test results has been observed. Figure 10, shows an example of the load versus flexural displacement curves for all 3 original samples. Both curves are practically linear until the maximum load is reached, where – a sudden drop occurs.

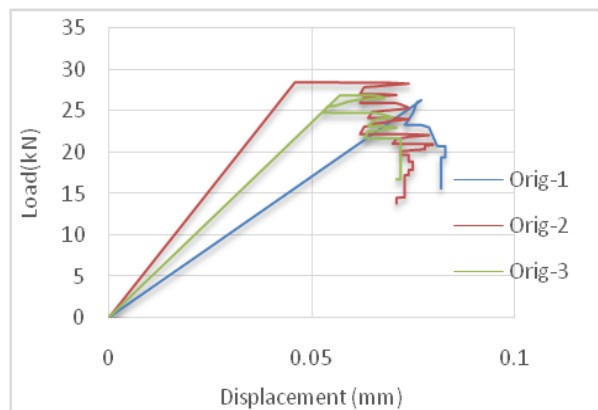


Figure 10-load–displacement curves: Original Specimens

Below figure 11 and 12 shows the load versus flexural displacement curves for AVGAS 100LL and ATF. From below load versus flexural displacement curves. It can be seen that the specimens immersed into ATF effect more than the specimens submerged into AVGAS100LL.

From below figure it is possible to conclude that the ATF effect the Flexure properties of GFRP more than AVGAS 100LL.

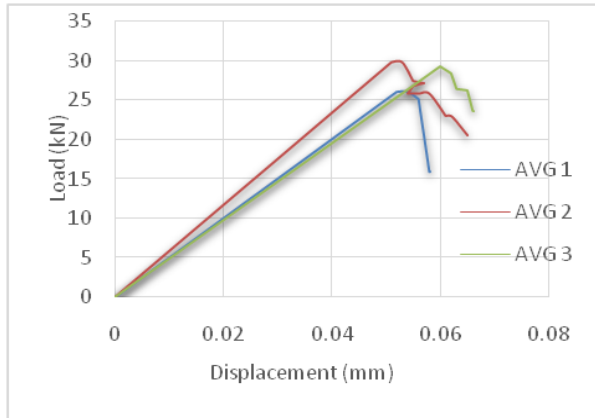


Figure 11- Typical load–displacement curves: AVGAS 100LL Specimen

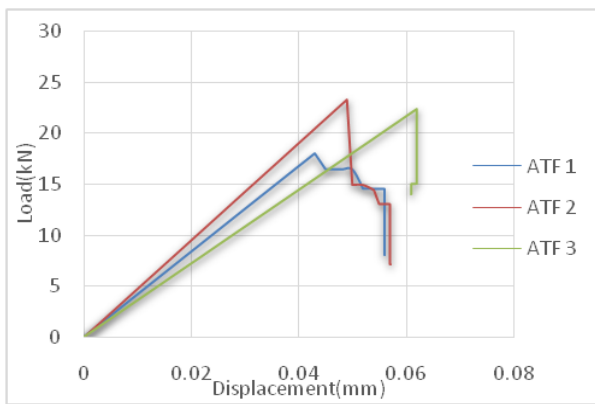


Figure 12- Typical load–displacement curves: ATF Specimen

For all conditions tested, the damage starts on the surface under compression following, posteriorly, different damage mechanisms. Relatively to the original specimens (Figure 13a), occurs compressive breakage of the longitudinal fibres in the curved crosshead nose contact region. According to Reis et al[24]. This phenomenon is consequence of the high compressive stress concentration in the pin load contact region associated to the low compressive strength of the fibres. For the samples immersed in the AVGAS 10LL (Figure 13b), associated to the fracture of the fibres in the compressor surface occurs significant delamination around the broken fibres. For the samples exposed to the ATF (Figure 13c), however, in this case, the fracture of the fibres in tensile surface was found. It is evident that these solutions promote matrix/fiberinterface degradation.

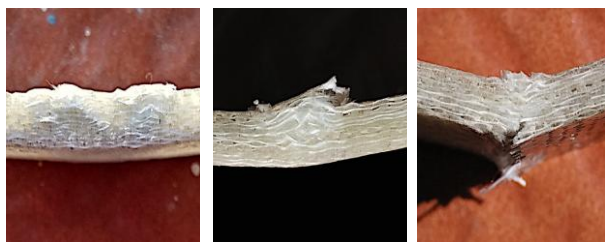


Figure 13- Failure mechanisms: (a) Original specimen (b) AVG specimen (c) ATF specimen

Table 7- Results of Flexure Parameters

Specimens	Load (N)	Deflection (mm)	Flexure Stress (Mpa)	Flexure Modulus (Mpa)
Orig 1	83	20.701	45.373	639.303
Orig 2	83	21.050	43.733	621.872
Orig 3	72	21.684	39.360	598.904
AVG 1	62	15.929	35.533	476.944
AVG 2	67	20.585	36.627	451.868
AVG 3	71	23.509	38.813	488.274
ATF 1	56	14.527	30.613	438.237
ATF 2	57	13.086	31.160	449.237
ATF 3	62	22.367	33.893	450.237

Table 8- Effect of the solutions on bending properties

Specimens	Aver. Flexural Stress (Mpa)	Std. dev. (Mpa)	Aver. Flexural Modulus (Mpa)	Std. dev. (Mpa)
Orig	42.82	3.108	620.026	20.277
AVG	39.99	1.702	472.362	18.630
ATF	31.88	1.756	446.150	6.850

Table 8 presents the bending strength and the bending stiffness modulus, in terms of average values and respective standard deviations.

It can be notice that the Aver Flexural Stress and bending Stiffness modulus are lower for AVG and ATF than the original specimen. In case of AVG and ATF we can see that the ATF flexural properties are lower. It means the ATF effects on the GFRP are higher in comparison with AVG.

V. CONCLUSION

The Influence of aviation fuel on mechanical properties of glass fiber-reinforced plastic composite were conducted. This work studied the flexural properties of a glass fiber reinforcement plastic composite after immersion in AVGAS 100LL and in ATF. The glass fiber-reinforced plastic laminate (30*30cm²) was manufactured using Vacuum infusion process. Properties such as the flexural stress and flexural modulus were evaluated from experiment. The experiment leads us to the following conclusions obtained from this study:

Absorption of ATF fuel was more in specimens than AVGAS 100LL.

1. It is possible to conclude that both solutions affect the flexural stress and flexural modulus.
2. However, for all tests performed, the AVGAS 100LL promotes the lowest values comparatively to the ATF.
3. It was found that ATF is more affected on flexural properties than the AVGAS 100LL (as shown in figure 14 and 15).

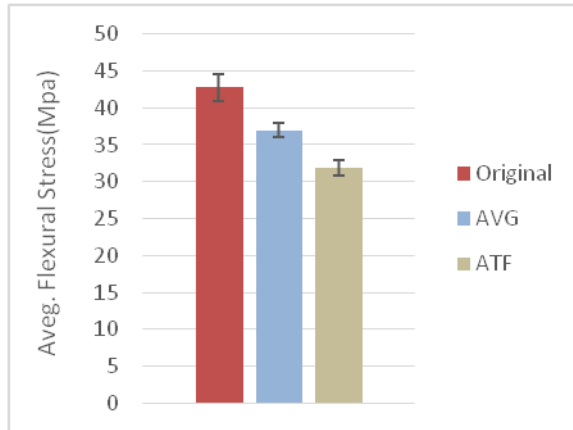


Figure 14- Average Flexural Stress

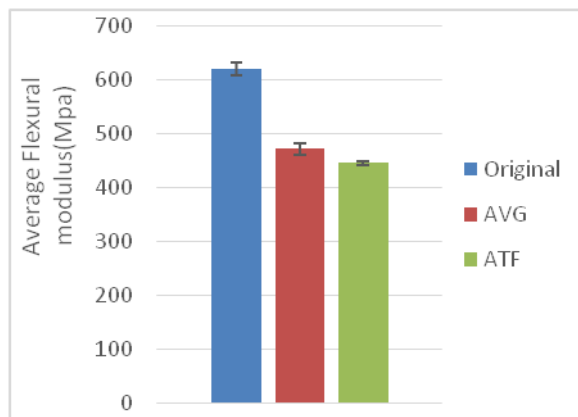


Figure 15- Average Flexural modulus

VI. SCOPE FOR FUTURE WORK

There is a very wide scope for future scholars to explore this area of research. This work can be further extended to study other mechanical properties of such composites like Soil degradation test, Pressure test and Burn out test for development of Hydrant pipeline network to transfer aviation fuel from the aviation fuel depot to all aircraft parking area in airport and in future replacing of Aircraft fuel pipe line with Glass fiber pipe line as it is so cheaper than other available composite materials.

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