

Effect of Temperature on the Mechanical Properties of Composite Materials Exposed to Aviation Fluids

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Abstract - Glass-fibre-reinforced plastic (GFRP) composites are widely used in aerospace structures due to their low weight, high specific strength and corrosion resistance. Their mechanical performance can be influenced by aviation-fuel exposure and temperature. This study investigates the thermal and mechanical behaviour of glass-fibre/epoxy composites exposed to aviation fuels. GFRP panels were fabricated by hand lay-up using 200 gsm glass fibre and LY556 epoxy resin with HY951 hardener at a 100:10 ratio. Approximately 350 × 350 mm panels with 3 mm thickness were fabricated and machined by water-jet cutting for impact, tensile and flexural testing. Thermal analysis was performed over the recorded temperature range to evaluate temperature-dependent behaviour and thermal degradation. Specimens were immersed in ATF and OX38 and exposed for seven days at 50 °C and 80 °C. Impact testing used a drop-weight method, while tensile and three-point flexural tests were conducted using a universal testing machine. The results showed changes in mechanical behaviour after fuel exposure, with ATF producing greater overall changes than OX38 and impact energy decreasing from the original condition. The findings indicate that thermal behaviour, fuel exposure and elevated temperature should be considered when evaluating GFRP composites for aerospace applications.

Key Words: GFRP composites, aviation fuel, ATF, OX38, impact strength, mechanical properties.

1. INTRODUCTION

Composite materials consist of two or more constituent materials whose combined properties differ from those of the individual constituents. In fibre-reinforced composites, the reinforcement provides much of the load-carrying capability while the matrix supports, protects and transfers load between the fibres. Such materials are used extensively in aircraft and aerospace structures because they can provide high strength-to-weight and stiffness-to-weight ratios.

Glass-fibre-reinforced plastic (GFRP) is one important class of polymer-matrix composite. The source project identifies

advantages including weight saving, improved torsional stiffness and impact behaviour, fatigue endurance, corrosion resistance and reduced maintenance requirements. Aerospace structures are nevertheless exposed to mechanical, thermal and chemical environments during service, and these conditions may influence composite performance.

The present work focuses on the effect of aviation-fuel exposure at elevated temperature on a glass-fibre/epoxy laminate. The study compares specimens exposed to ATF and OX38 for seven days at 50 °C and 80 °C and evaluates their impact, tensile and flexural responses against the original material condition.

2. MATERIALS AND METHODOLOGY

A. Materials

The laminate was fabricated using 200 gsm glass fibre, LY556 epoxy resin and HY951 hardener. A Mylar sheet and aluminium plates were used during panel fabrication, with petroleum wax as a release agent. The source report specifies a resin-to-hardener ratio of 100:10 by weight.

Table 1. Materials used for GRPF panel fabrication

Material / Item	Specification	Purpose
Glass fibre	200 gsm	Reinforcement
LY556 epoxy	100 parts by weight	Matrix
HY951 hardener	10 parts by weight	Curing agent
Mylar sheet	20 microns	Surface/release layer
Aluminium plate	450 x 450mm	Panel support
Petroleum wax	-	Release agent

B. Panel Fabrication

Glass-fibre pieces were cut to 350×350 mm. For a target thickness of 3 mm, thirteen fibre pieces were used. Approximately 400 g of glass fibre was weighed and the corresponding resin and hardener quantities were prepared according to the 100:10 ratio. The aluminium plate and Mylar sheet were waxed, the fibre layers were placed sequentially, and the resin-hardener mixture was applied between layers. A hand roller was used to apply pressure and assist impregnation. The assembled panel was covered with a waxed Mylar sheet and aluminium plate, loaded with weight and allowed to settle for one day.



Fig 1. Completed Panel

C. Specimen Preparation and Exposure

The completed panels were cut by water-jet machining. The reported specimen dimensions were 100×100 mm for impact testing, 250×25 mm for tensile testing and 150×25 mm for flexural testing. Water-jet cutting was selected because it avoids the heat-affected zone associated with thermal cutting and can reduce the risk of heat-related damage to composite material.

After specimen preparation, the specimens were completely submerged in two aviation fuels identified in the project as ATF (clear to straw-colored) and OX38 (brown). The specimens were placed in a furnace at 50°C and 80°C for seven days before mechanical evaluation.



Fig2. Immersed ATF specimen taken out from furnace after 7 days

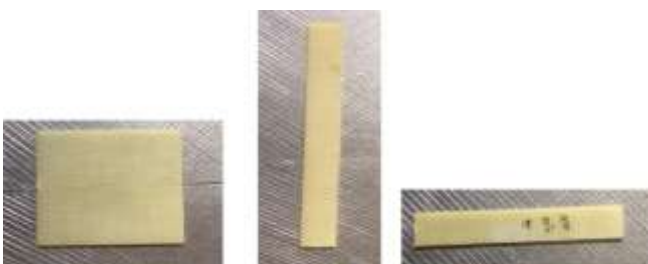


Fig3. Immersed OX₃₈ specimen taken out from furnace after 7 days

D. Mechanical Testing

Impact behaviour was evaluated using a drop-weight test. The project used the relation $E = mgh$, where E is impact energy, m is the dropping mass, g is gravitational acceleration and h is the drop height. The reported drop height was 1.2 m and g was taken as 9.81 m/s^2 .

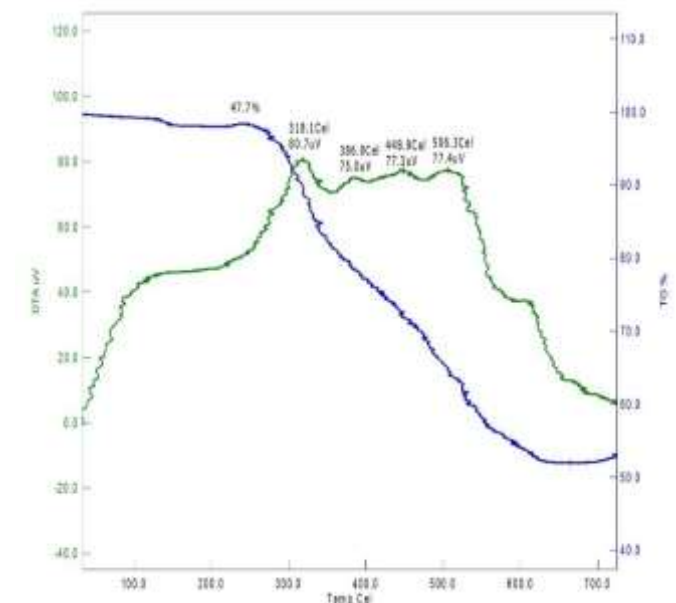
Tensile behaviour was evaluated by controlled tension until failure. Flexural behaviour was evaluated by a three-point bending test using an FSAM-100 universal testing machine with a 100 kN load cell and WINUTM software. The flexural test was performed at a displacement rate of 5 mm/min, with three specimens tested for each condition.

3. RESULTS

A. Glass Transition (T_g) -Thermal Analysis

Thermal analysis was used to examine the temperature-dependent behaviour of the composite material. The project report records a thermal-analysis run from approximately 100°C to 700°C . In the final report, the thermogravimetric percentage was about 53.5–53.7% near $726\text{--}727^\circ\text{C}$, indicating substantial material transformation at the high-temperature end of the recorded range.

Graph 1. Thermal analysis



The above graph shows at what point the powder (5.589 mg.) of composite material undergoes viscous or rubbery state when temperature rises from 100 to 700 degree Celsius.

Table 2. Selected initial thermal-analysis values

Time min	Temp in degree Celsius	TG %
3.808333	124.8893	99.02648
3.841667	125.5176	99.00957
3.883333	132.9656	98.98647

In the above table as temperature is increased the TG% is falling down slowly. Also, time is an important factor that shows the breakage of composite particle. When temperature reach to 700 degree Celsius (in Table 3), about 50 % of composite particle is changing to viscous state. This results how much temperature the composite panel can withstand and can be taken for different testing procedures to prove its mechanical properties.

Table 3. Selected final thermal-analysis values

Time min	Temp in degree Celsius	TG %
35.01667	727.0785	53.50043
35.05	726.3204	53.57483
35.09167	725.8347	53.67122

B. Impact Test

The original specimens recorded an average impact energy of 70.8 J in the project table. After seven days of exposure, the reported averages were 57.7 J for ATF at 50 °C, 55.3 J for ATF at 80 °C, 58.2 J for OX38 at 50 °C and 56.4 J for OX38 at 80 °C.



Fig 4. Impact test (Dimension: 100*100mm)

Condition	Fuel	Temperature	Average impact energy (J)
Original	None	Room	70.8
Exposed	ATF	50 °C	57.7
Exposed	ATF	80 °C	55.3
Exposed	OX38	50 °C	58.2
Exposed	OX38	80 °C	56.4

Table 4. Average impact energy reported in the project

Table 4.1. Impact test values

SPECIMEN	ORIGINAL		ATF				OX38			
	m (Kg)	E (J)	50°C		80°C		50°C		80°C	
			m (Kg)	E (J)	m (Kg)	E (J)	m (Kg)	E (J)	m (Kg)	E (J)
S 1	6	70.8	5	57.6	5	55.3	5	58.1	5	56.3
S 2	6	70.6	5	57.8	5	55.4	5	58.3	5	56.6
S 3	6	70.9	5	57.7	5	55.1	5	58.2	5	56.4
AVERAGE	70.8 J		57.7 J		55.3 J		58.2 J		56.4J	

Using $E = mgh$ with $h = 1.2$ m and $g = 9.81$ m/s², the project converted the recorded impact energies to equivalent dropping masses. The calculated values were approximately 6.014 kg for the original condition, 4.901 kg for ATF at 50 °C, 4.697 kg for ATF at 80 °C, 4.943 kg for OX38 at 50 °C and 4.791 kg for OX38 at 80 °C.

C. Tensile Test

Tensile tests were conducted on original, ATF-exposed and OX38-exposed specimens at the stated temperature conditions. The project report records load-versus-elongation curves for virgin material, ATF at 50 °C, OX38 at 50 °C, ATF at 80 °C and OX38 at 80 °C. The reported interpretation states that the OX38 specimens showed higher tensile values than ATF at both 50 °C and 80 °C, while OX38 showed comparatively limited variation between the two exposure temperatures.

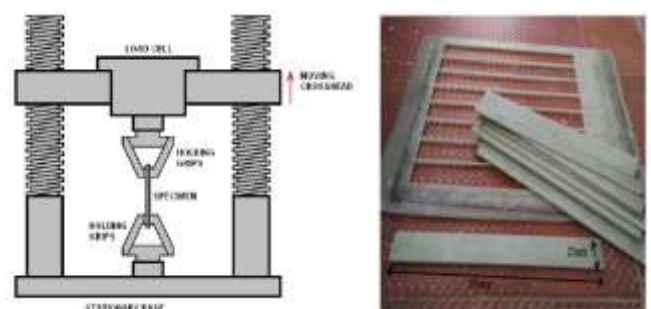
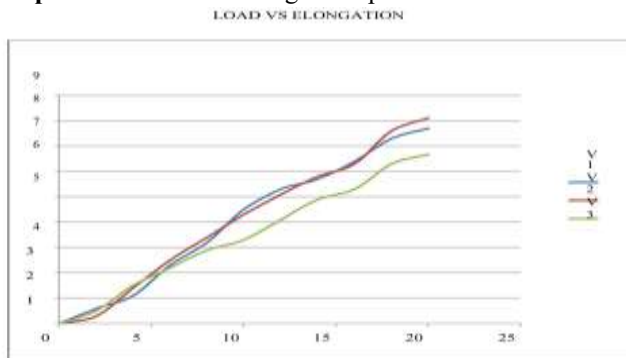
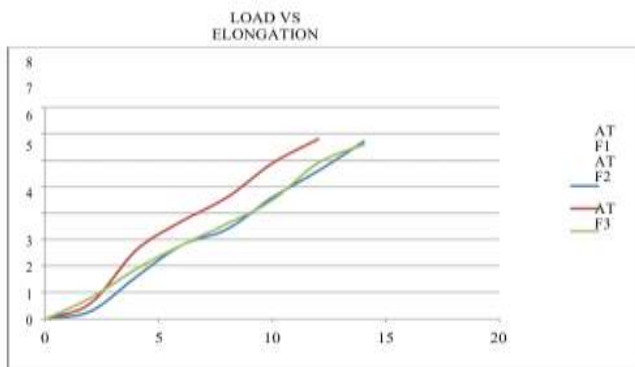
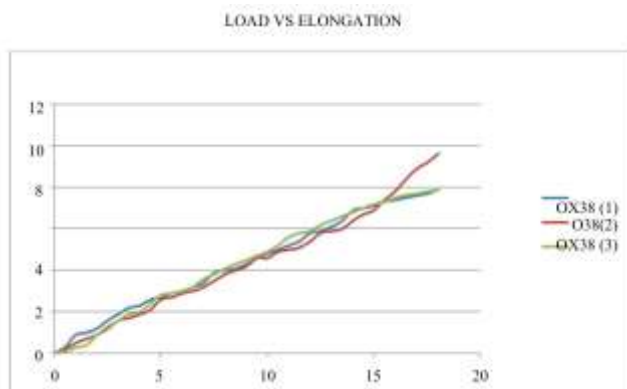
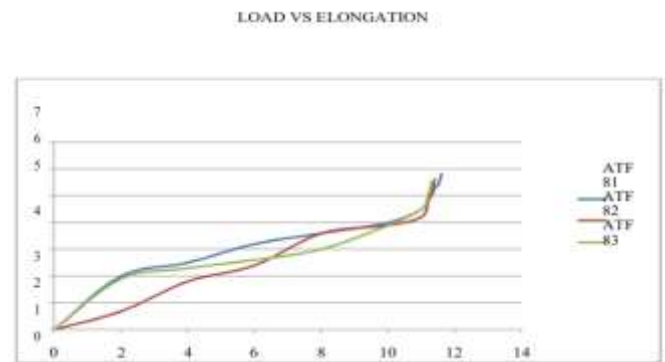
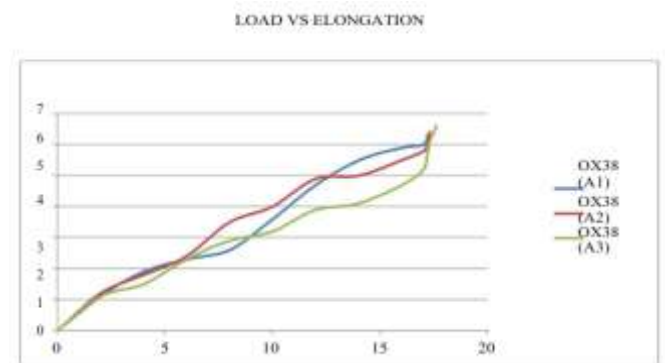


Fig 5. Tensile test (Dimension:250*25mm)

Table 5. Tensile test values

SPECIMEN	ROOM TEMP		50°C				80°C			
	ORIGINAL		ATF		OX38		ATF		OX38	
	L (kN)	E (mm)	L (kN)	E (mm)	L (kN)	E (mm)	L (kN)	E (mm)	L (kN)	E (mm)
S1	19.6	7.8	13.9	6.7	18.3	7.8	11.6	5.8	17.3	6.4
S2	20.3	8.1	12.8	6.8	18.6	9.7	11.4	5.6	17.2	6.3
S3	19.8	6.7	13.6	6.5	18.4	7.9	11.3	5.5	17.6	6.6

Graph 2. Tensile test of virgin samples

Graph 3. Tensile test of ATF at 50°C

Graph 4. Tensile test of OX38 at 50°C

Graph 5. Tensile test of ATF at 80°C

Graph 6. Tensile test of OX38 at 80°C


D. Flexural Test

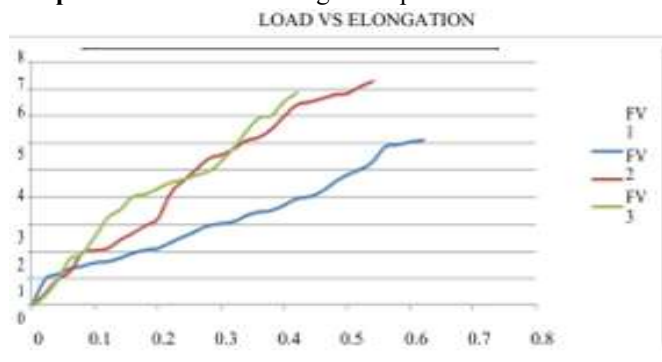
Three-point flexural testing was performed on original and fuel-exposed specimens. The project records flexural strength, flexural modulus and maximum load at fracture from the universal testing machine and presents load-versus-elongation curves for ATF and OX38 at 50 °C and 80 °C. The source material supports the conclusion that fuel exposure and temperature influenced the flexural behaviour.


Fig 6. Flexural test (Dimension: 150*25mm)

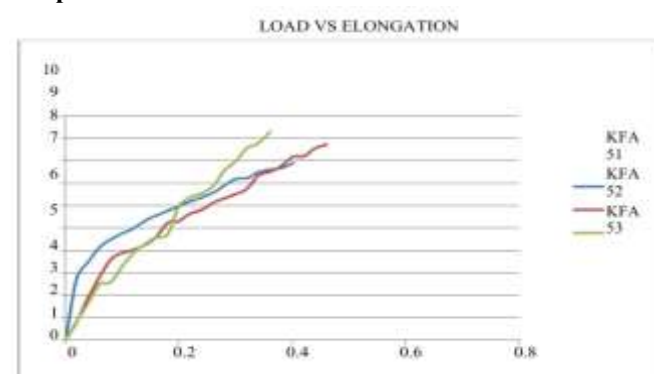
Table 6. Flexural test values

SPECIMEN	ORIGINAL		50°C				80°C			
			ATF		OX38		ATF		OX38	
	L (kN)	E (mm)	L (kN)	E (mm)	L (kN)	E (mm)	L (kN)	E (mm)	L (kN)	E (mm)
S1	0.247	8.598	0.391	8.055	0.425	9.81	0.657	7.765	0.77	9.233
S2	0.539	8.253	0.464	8.73	0.457	9.234	0.697	9.843	0.721	9.233
S3	0.347	8.178	0.364	9.291	0.489	10.16	0.750	8.936	0.709	8.986

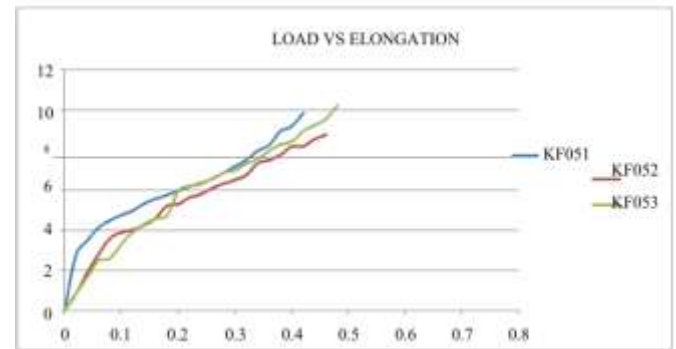
Graph 7. Flexural test of virgin samples



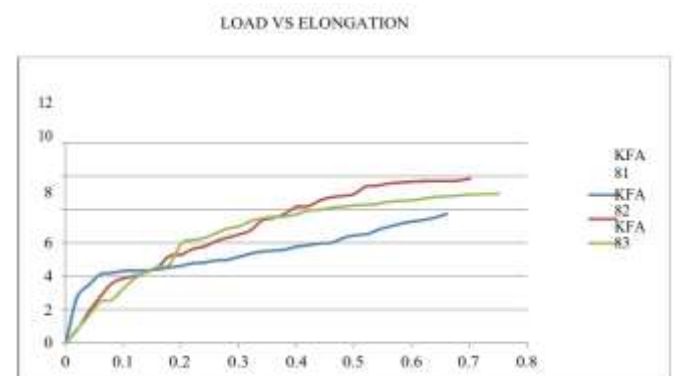
Graph 8. Flexural test of ATF 50°C



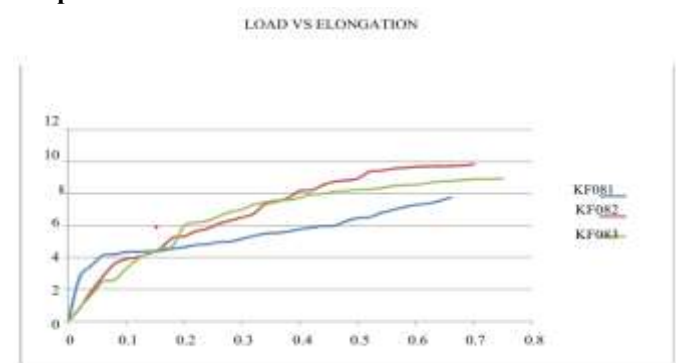
Graph 9. Flexural test of OX38 at 50°C



Graph 10. Flexural test of ATF at 80°C



Graph 11. Flexural test of OX38 at 80°C



4. DISCUSSION

The experimental results demonstrate that the GFRP laminate did not retain the same mechanical response after exposure to aviation fuels. The Glass Transition (T_g) thermal analysis showed temperature-dependent changes in the composite material as the temperature increased over the recorded range. Impact energy decreased from the original average of 70.8 J to values between 55.3 J and 58.2 J after fuel exposure. Within the reported conditions, the ATF-exposed specimens showed lower average impact energy than the corresponding OX38 specimens at both temperatures.

The project interprets ATF as producing greater overall interaction with the GFRP specimens than OX38. The tensile results also indicate higher recorded values for OX38 than ATF at 50 °C and 80 °C. The change in behaviour with

temperature suggests that fuel exposure should not be considered independently of the thermal environment.

The observations are consistent with the broader literature reviewed in the project, where temperature, moisture, chemical exposure and exposure duration have been associated with changes in composite strength, stiffness, impact response and matrix condition. The present experiment is limited to the selected GFRP system, two fuel conditions, two temperatures and a seven-day exposure period; therefore, the results should be interpreted within those experimental boundaries.

5. CONCLUSION

The study investigated the influence of aviation-fuel exposure and temperature on the thermal and mechanical behaviour of a glass-fibre-reinforced plastic composite. GFRP laminates were fabricated by hand lay-up and exposed to ATF and OX38 for seven days at 50 °C and 80 °C, after which thermal, impact, tensile and flexural properties were evaluated.

- The Glass Transition (T_g) thermal showed temperature-dependent changes in the composite material, indicating changes in its thermal behaviour as the temperature increased.
- ATF showed greater absorption or interaction with the GFRP specimens than OX38 in the project observations.
- Exposure to both ATF and OX38 affected the impact, tensile and flexural behaviour of the composite.
- Impact strength decreased after exposure to both aviation fuels; the average recorded impact energy was 70.8 J for the original condition and 57.7, 55.3, 58.2 and 56.4 J for the four exposed conditions.
- ATF produced a greater overall change in mechanical properties than OX38 according to the project interpretation.
- Increasing the exposure temperature from 50 °C to 80 °C influenced the mechanical behaviour of the composite.
- The thermal and mechanical results indicate that aviation-fuel exposure and elevated temperature should be considered when evaluating GFRP materials for aerospace applications.

6. FUTURE SCOPE

Further work may investigate pressure resistance, fatigue behaviour, fire and flammability characteristics, thermal degradation and longer fuel-exposure periods. Additional studies may vary fibre orientation, resin system, fuel type, exposure duration and temperature. The feasibility of using GFRP in selected aircraft components can also be examined subject to structural, safety, durability and certification requirements.

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