Department Of Aerospace Engineering
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AS2070 Course Project

Tensile & Creep Testing of Composites

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Name	**Contribution**
Harsh	Theoretical Analysis + Experiment
Mahesh	Composite Design and Sample Preparation
Kusuma	Dogbone Preparation
Divjot	Data Analysis
Surya	Sample Preparation and Modifications

Table 1: Team Members and Their Contributions

Everyone worked on the Report and PPT

1 Aim

1.Tensile of laminated composites
In this experiment, we subject the laminated composites to tensile force and plot the stiffness curve.
2.Creep testing for laminated composites
In this experiment, we subject the laminated composite to a constant tensile load which is below the yield strength at a certain temperature and plot the creep curve.

2 Apparatus

- Laminate sample (GFRP)
- epoxy resin & hardener
- Water-jet Cutter
- Creep Testing Machine
- Universal Testing Machine (UTM)

3 Procedure

- Cut the specimen and tabs to the required size and shape using a water-jet cutter.

- Attach the tabs to the test specimen using epoxy resin and hardener.
- For tensile testing use the specimen with tabs and grip it in the utm machine

- Apply some pre-load according to the specimen and carry out the experiment.
- For creep testing just place the dog bone specimen into the machine and set the required load and temperature and observe the creep plot

4 Theory

4.1 Tensile Testing of Composite Materials

Tensile testing is essential for evaluating the mechanical behavior of composite materials, such as tensile strength, stiffness, and failure modes. Unlike metals, which deform plastically and fail uniformly, composites fail through multiple localized mechanisms due to their heterogeneous structure and anisotropic properties.

Two primary methods are used in tensile testing: **force control** and **displacement control**. While force-controlled testing increases load at a constant rate, it may lead to unstable failure in composites once damage initiates. Therefore, **displacement-controlled testing** is preferred, as it applies strain at a constant rate, enabling a more stable and progressive failure process and allowing for the capture of post-peak behavior.

During displacement-controlled testing, failure typically occurs in stages: matrix cracking, fiber-matrix debonding, delamination, and fiber breakage. These mechanisms evolve as strain increases, and they are reflected in the force-displacement curve, which starts linearly, becomes nonlinear as damage accumulates, and drops after fiber failure.

Tensile testing is carried out using a **universal testing machine (UTM)** equipped with extensometers or optical systems like Digital Image Correlation (DIC) for strain measurement. Proper gripping, often with end-tabs, and careful specimen preparation are critical to avoid premature failure.

This testing method is vital for the design and validation of composite components in industries such as aerospace and automotive, where weight and performance are key concerns.

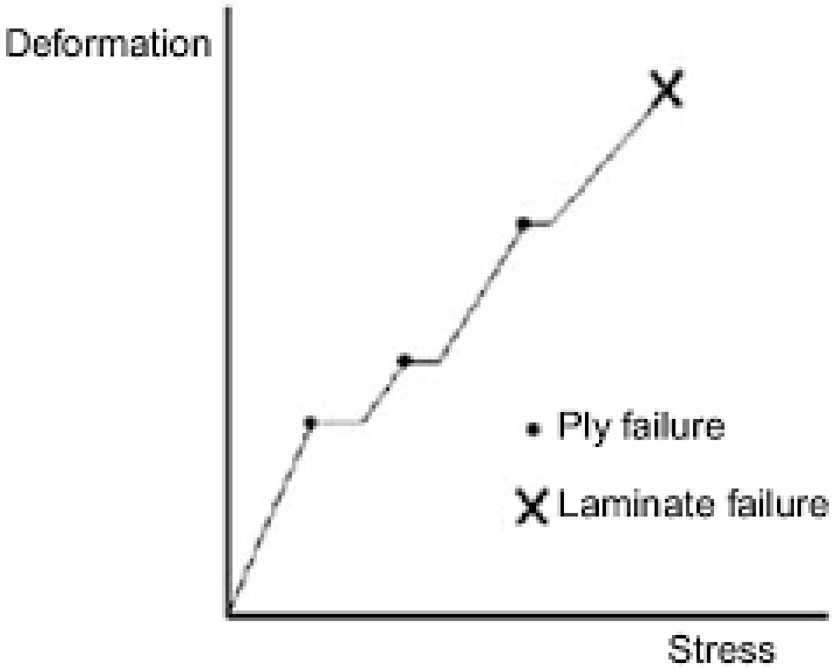


Figure 1: Laminate Tensile Testing Graph

4.2 Creep Testing of Laminates

Creep is the time-dependent, permanent deformation of materials under constant stress, especially at elevated temperatures (typically above 0.4 times the melting temperature in Kelvin). It occurs in three distinct stages: **primary creep**, where the strain rate decreases due to work hardening; **secondary creep**, characterized by a steady strain rate due to a balance between work hardening and recovery; and **tertiary creep**, where the strain rate accelerates rapidly due to internal damage, leading to failure.

High temperatures significantly influence creep behavior. Increased thermal energy enhances atomic diffusion and dislocation mobility, accelerating the creep rate. This results in reduced material strength and lifespan, making creep analysis critical for components operating in high-temperature environments such as gas turbines, nuclear reactors, and aerospace engines.

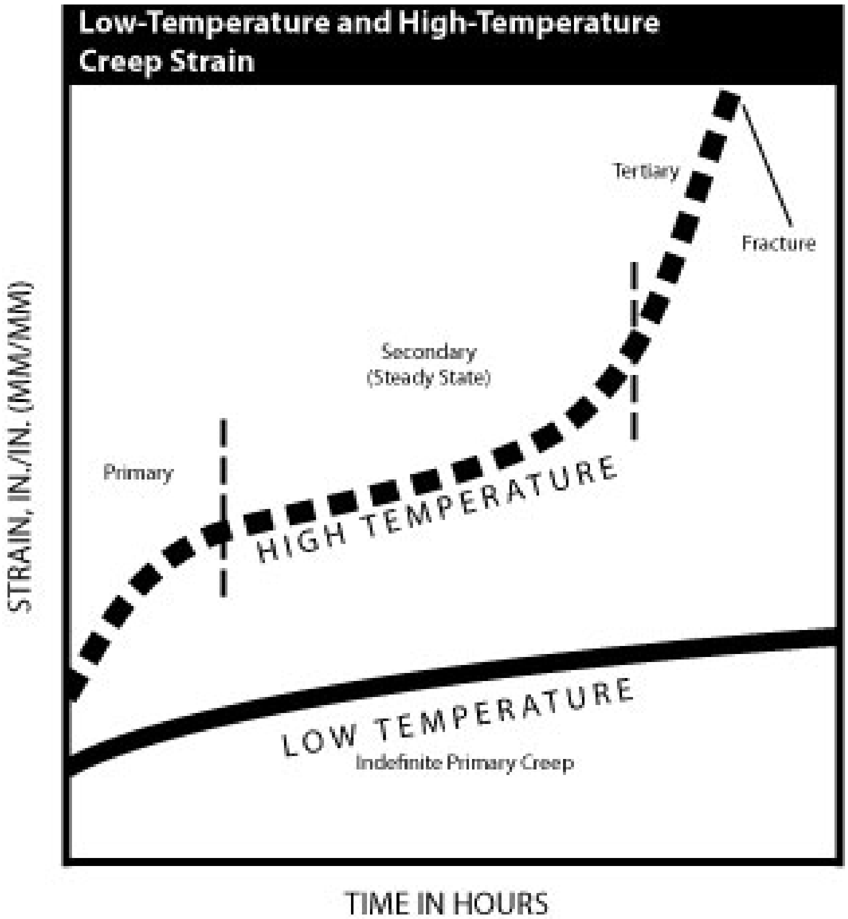
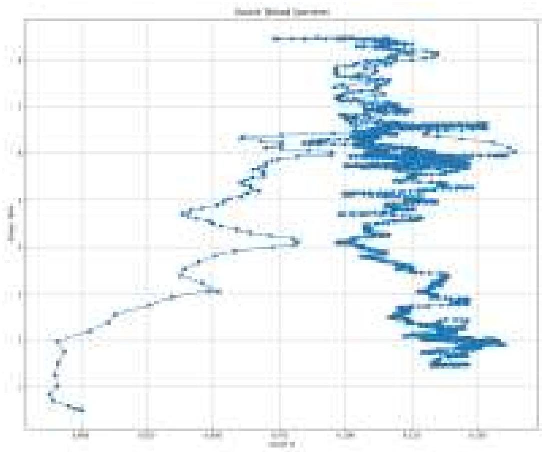


Figure 2: Effect of Temperature on Creep Curve

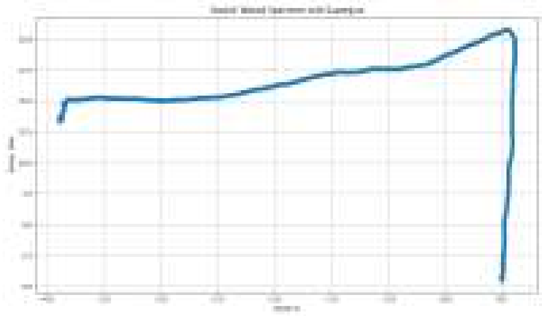
5 Observation

5.1 Tensile Testing

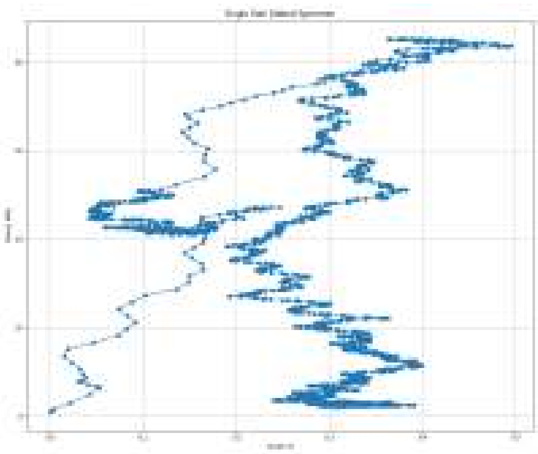
Initially, tensile testing was carried out on a rectangular specimen tabbed on both sides. However, as seen in Figure 1(a), the setup was prone to slipping due to the shearing of the tab and the specimen joined through epoxy.
Hence, for the next tensile test, superglue was used to strengthen the tab and the specimen's connection. As seen in Figure 1(b), the stress-strain curve is almost linear until stress reaches 20 MPa, after which it slips. Upon removal, it was observed that two of the four tabs were loose and fell down.
In the next tensile test (Figure 1(c)), we removed tabs from one side of the specimen. We observed two relatively linear and meaningful portions of the plot. Most of the plot, however, was ambiguous with erroneous effects.
For the fourth tensile test, we used a twin dog-bone-shaped specimen joined using epoxy. This was placed in the dog-bone-shaped jaws of the testing machine for the tensile test.



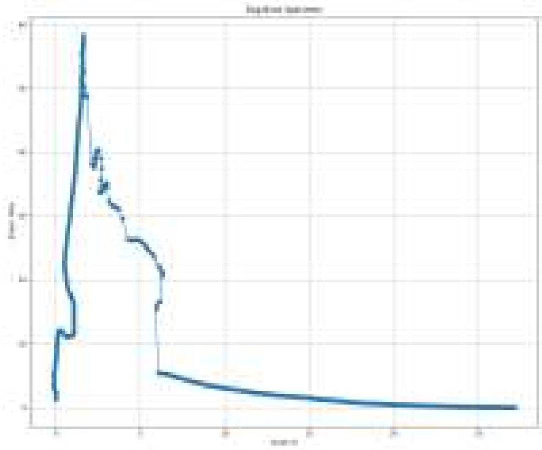
(a) Specimen with tabs on both sides



(b) Specimen with tabs on both sides, enhanced using superglue



(c) Specimen with tabs on one side only



(d) 2 Dog-Bone Shaped specimens stuck together

Figure 3: Plots obtained for Tensile Testing

5.2 Creep Testing

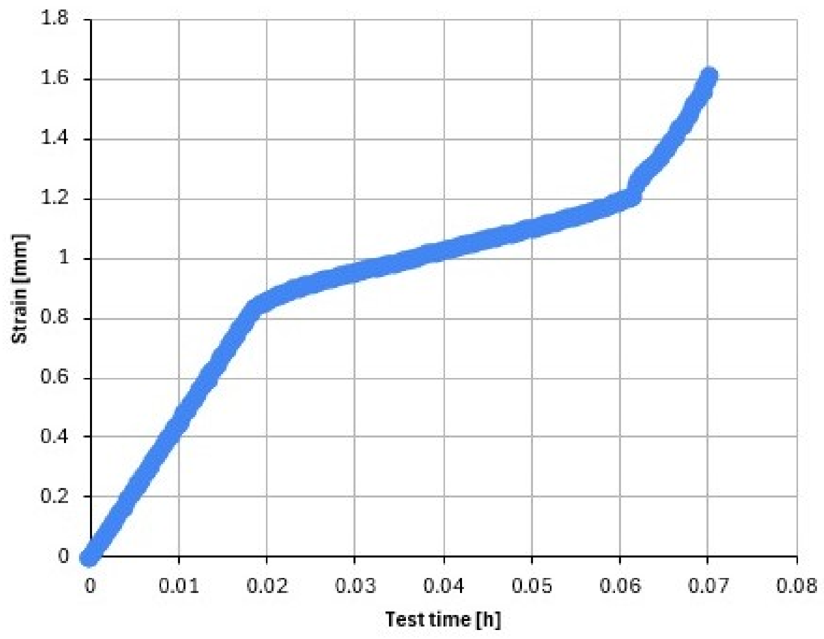


Figure 4: Plot for Creep test

6 Observations

From the creep curve obtained for composite materials, the following observations were made:

- The curve exhibited the typical three-stage behavior: an initial decreasing strain rate (primary creep), followed by a steady-state region (secondary creep), and a final accelerating strain rate leading to failure (tertiary creep).
- The secondary creep stage was more pronounced in composites, indicating better resistance to long-term deformation compared to pure metals.
- Creep resistance was strongly influenced by the type of matrix and reinforcement used; fiber-reinforced composites generally showed lower creep rates.
- Temperature had a noticeable effect, with higher temperatures resulting in faster transition to tertiary creep.

7 Sources of Errors

7.1 In preparing the specimen

- The resolution limit of the cutting tool (Water-jet cutter) poses a limit for accuracy and the cutting allowance which was not given has given a specimen with different dimensions.

- The difficulties in progressing with a small specimen and sticking tabs onto it made it difficult and allowed the epoxy layer between the tab and specimen to shear.
- Cutting the laminates into Dog-bone specimens made a few delaminate and could have caused it to fail earlier.
- Sticking two Dog-bones for tensile test using epoxy made it a complicated to analyse.

7.2 During the Experiment

- The Laser used in UTM which measures strain by locating 2 different grains on the specimen was not very good for a laminate, which might have caused minor errors.
- Since the creep machine with its furnace was designed to work at higher temperatures, the lower temperature set for the laminate might not be accurate.
- The dog bone may not fit exactly initially allowing for a little movement, giving inaccuracies at the beginning.

8 Conclusion

- Enough gripping area should be given to avoid the specimen from slipping.
- Machining allowance should be given while preparing specimens and extra specimens shall be made to compensate for any mistakes.
- Using a bigger specimen for Tensile Test will reduce the difficulties in the process of preparation of sample (attaching tabs, will provide larger gripping area)
- Higher temperatures result in faster creep propagation as seen that the structure fails in under 5 min.
- The specimen undergoes all three stages of creep followed by a brittle facture and no plastic deformation.
- The secondary stage of creep is comparatively larger indicating better resistance to long-term deformation compared to pure metals.

9 Acknowledgments

We would like to express our gratitude to Prof. Nidish, for giving us this opportunity. We would also like to thank Prof. Ravi Shankar for providing us the his Lab for our Project and Prof. Prashant for his insights on ASTM Standards and providing us with Composite Laminates.
We would also like to thank the Research Scholars who helped us throughout our Project: Priyanka, Sailesh, Sabari, and Arjun.