DEPARTMENT OF AEROSPACE ENGINEERING

Indian Institute of Technology Madras

AS2070: Aerospace Structural Mechanics

Group F

Project: Area Dependence of Failure in Fibers

Module 3: Introduction to Failure

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1 Aim

This experiment studies how the tensile failure characteristics of brittle fibers vary with cross-sectional area. The critical stress leading to fracture is analyzed across specimens of different diameters but fixed gauge length.

2 Materials Used

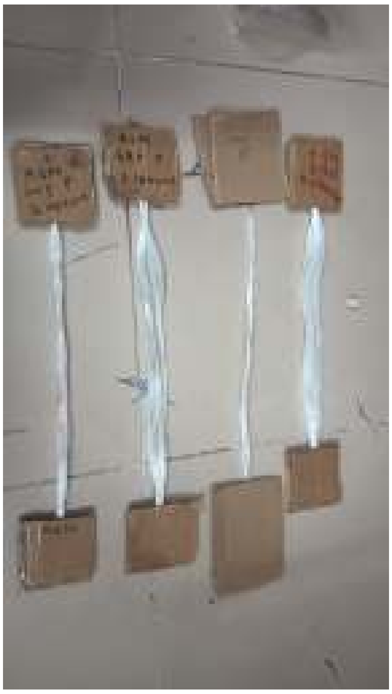

Figure 1: Specimen

Figure 2: Glass Fiber Sheet

- Universal Testing Machine
- EWR 600 Roving Fiber Sheet
- Glass fiber specimens of different diameters
- Mounting cardboards
- CYNO 777P Adhesive
- Data acquisition software

Figure 3: UTM

3 Theory

Tensile stress is a measure of the internal resistance of a material to deformation when subjected to an applied tensile force. It is defined as the force applied per unit area of the material. The formula for tensile stress is given by:

$$\sigma = \frac{F}{A}$$

where σ is the tensile stress, F is the applied force, and A is the cross-sectional area of the material.
In this experiment, the material under investigation is EWR roving 600, a type of reinforcing fiber commonly used in composite materials. The objective is to determine the maximum tensile stress that the material can withstand when subjected to different loading conditions. To achieve this, we use thread samples of varying numbers, ranging from 1 to 5 threads, each of 30 cm in length.
The threads are assumed to be cylindrical in shape, with a known diameter of 0.277 mm for a single thread. The cross-sectional area of each thread is calculated using the formula for the area of a circle: (The actual fibers had a rectangular cross-section, but were assumed to be cylindrical with a nominal diameter of 0.277 mm, based on standard GSM-to-diameter conversions)

$$A = \frac{\pi d^2}{4}$$

where d is the diameter of the thread. For each sample, the area is determined based on the number of threads used, with the total area increasing as more threads are included in the sample.
As the sample is subjected to a tensile load, the material undergoes deformation. The force is gradually increased, and the corresponding stress is calculated at each load increment. The maximum tensile stress is the highest value of stress achieved before the material fails or reaches its breaking point.
The key objective of this experiment is to explore how the tensile stress varies with the number of threads in the sample. As the number of threads increases, the cross-sectional area increases, which, according to the stress formula, should result in a decrease in the maximum tensile stress for a given force. This is because the force is distributed over a larger area, reducing the stress experienced by each individual thread.
By performing this experiment, we aim to establish a clear understanding of the relationship between tensile stress and cross-sectional area for the EWR roving 600 material. The data obtained will provide valuable insights into how the material behaves under different loading conditions, and it will help in determining the material's mechanical properties, such as its strength and load-bearing capacity.

4 Procedure

- Compute the cross-sectional area using the formula: $A = \frac{\pi d^2}{4}$, where $d = 0.277\,\text{mm}$.
- Cut the threads to a length of 30 cm, designating 5 cm at each end as the grip length.
- Attach the threads to cardboard tabs using adhesive.

- Allow the adhesive to dry to prevent slippage during testing.
- Mount the sample on the Universal Testing Machine (UTM) and apply a uniaxial tensile load at a constant rate of 13 mm/min.
- Record the force until the thread breaks, and extract the maximum load data.
- Calculate the tensile stress at failure using the formula: $\sigma = \frac{F}{A}$.
- Repeat the procedure for thread bundles of 1 to 5 fibers to assess area dependence.

5 Calculation

Dataset 1: Fiber diameter $d = 0.277\,\text{mm} = 2.77 \times 10^{-4}\,\text{m}$

$$A = \frac{\pi d^2}{4} = \frac{\pi (2.77 \times 10^{-4})^2}{4} = 6.03 \times 10^{-8}\,\text{m}^2$$

$$F_{\text{max}} = 613.5\,\text{N} \quad \Rightarrow \quad \sigma_{\text{max}} = \frac{F}{A} = \frac{613.5}{6.03 \times 10^{-8}} = 10.18 \times 10^9\,\text{Pa} = 10.18\,\text{GPa}$$

6 Results and Analysis

Maximum Tensile Stress for Each Sample:

No. of Fibers	Area (mm^2)	Max Stress (GPa)
1	0.0603	10.180
2	0.1210	5.111
3	0.1808	2.141
4	0.2411	2.024
5	0.3013	1.676

Table 1: Max Stress vs. Fiber Cross-Sectional Area

7 Graphical Representation

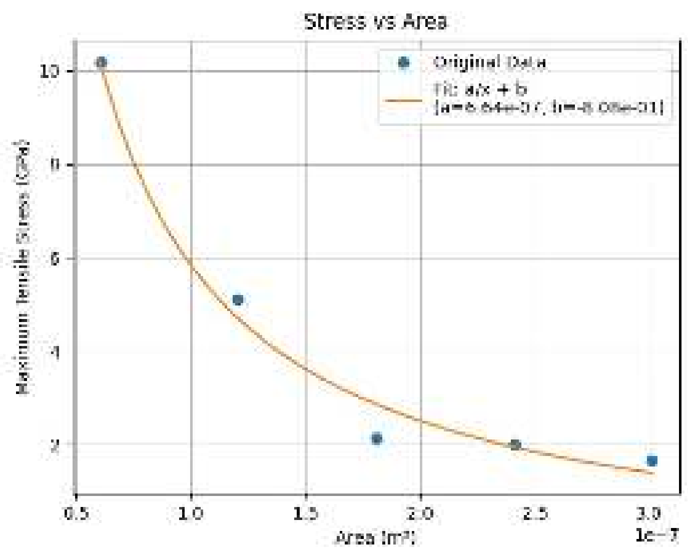

Figure 4: Stress vs. Cross-sectional Area

7.1 Stress vs Strain Plots for Different Number of Threads

The following figures show the stress vs strain behavior for samples containing 1 to 5 threads. Each plot corresponds to one sample. A note is provided for the fifth sample due to a manual adjustment during testing.

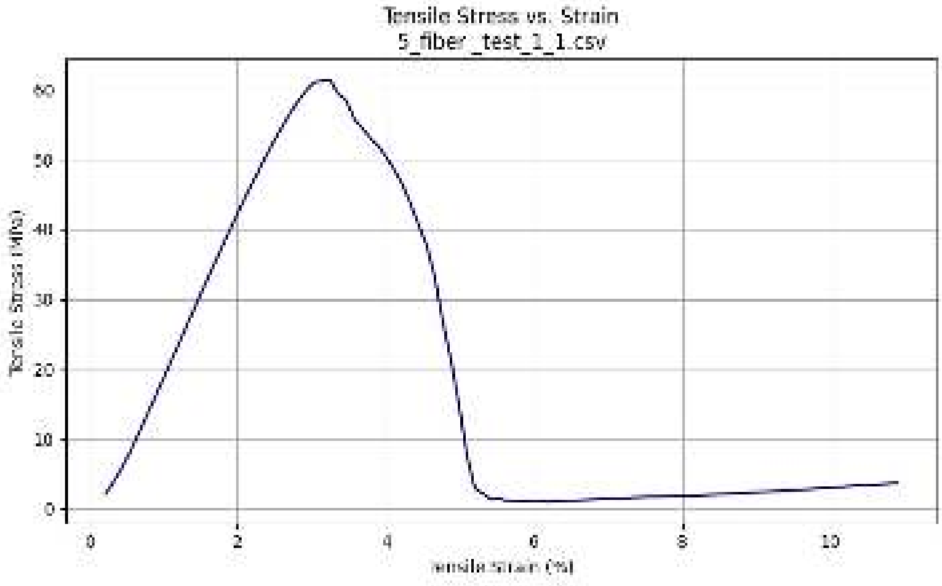

Figure 5: Stress vs Strain plot for 1 thread

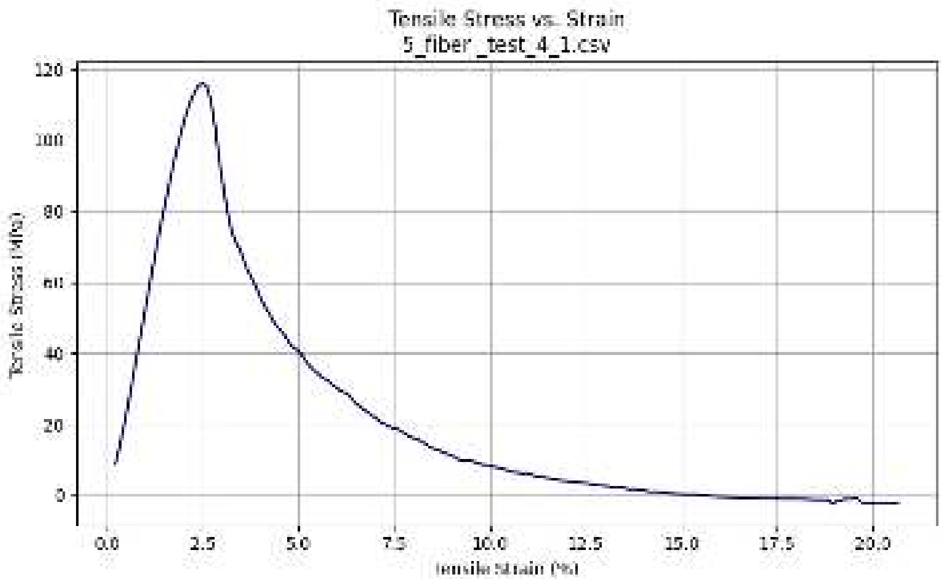

Figure 6: Stress vs Strain plot for 2 threads

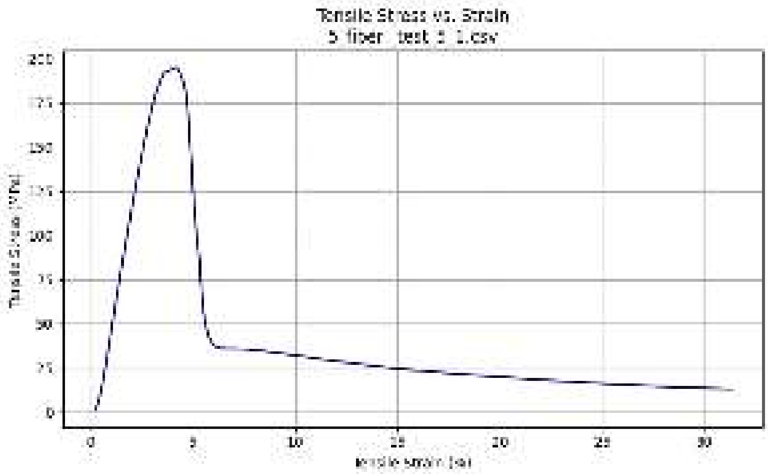

Figure 7: Stress vs Strain plot for 3 threads

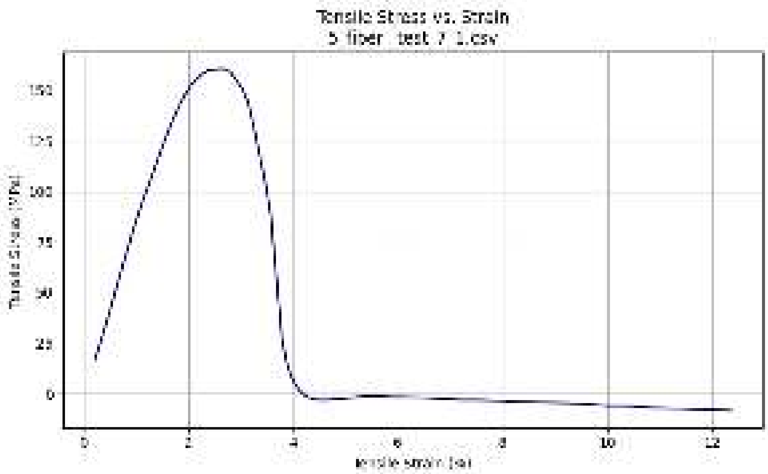

Figure 8: Stress vs Strain plot for 4 threads

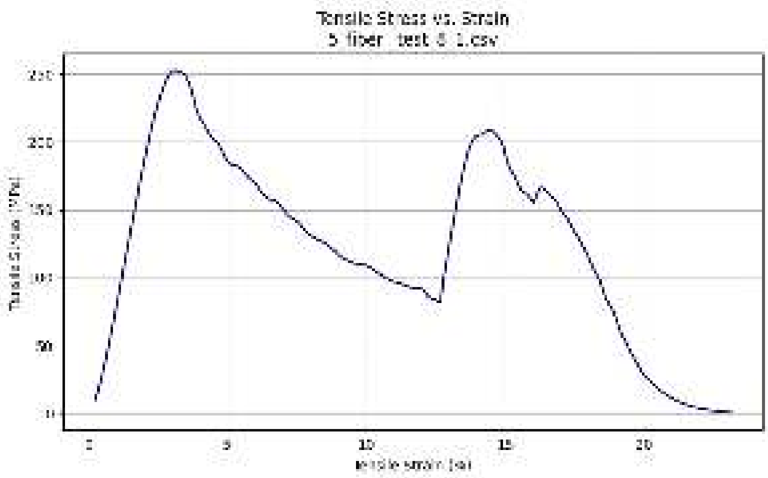

Figure 9: Stress vs Strain plot for 5 threads (It went up again when the UTM was being tightened manually after the slippage of cardboard)

Observation:

- As the cross-sectional area increases, the stress decreases.
- Larger areas are more likely to have flaws, which makes brittle fibers weaker.

8 Sources of Error

- Cardboard pieces were used to grip the fibers in the UTM, but they sometimes slipped, which shows the grip was weak.
- Misalignment happened when loading multiple fibers together, as they were not properly stuck or held in place.
- Some fibers were not pulled evenly, which could affect the stress readings.
- Human error during setup and alignment may have caused variation in results.

9 Conclusion

- Stress was found to decrease as the cross-sectional area of the fibers increased.
- This confirms that brittle materials like glass or ceramic fibers are sensitive to flaws.
- Larger areas have a higher chance of having flaws, which leads to lower strength.
- Understanding the relationship between cross-sectional area and tensile strength is crucial for the design of materials in industries such as aerospace, construction, and textiles, where fiber strength and reliability are critical for safety and performance.

10 Contributions

- **Bhavesh** – Responsible for specimen preparation, report writing, and presentation (PPT).
- **Siddhi** – Responsible for specimen testing, report writing, and presentation (PPT).
- **Anushka** – Responsible for specimen preparation, report writing, and presentation (PPT).
- **Tanishq** – Responsible for specimen testing and report writing.
- **Shiven** – Responsible for conducting the experiment and preparing the presentation (PPT).

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