IIT MADRAS
Indian Institute of Technology Madras

Area Dependence of Failure in Fibers

Module 3: Introduction to Failure

Group F

AS2070 – Aerospace Structural Mechanics

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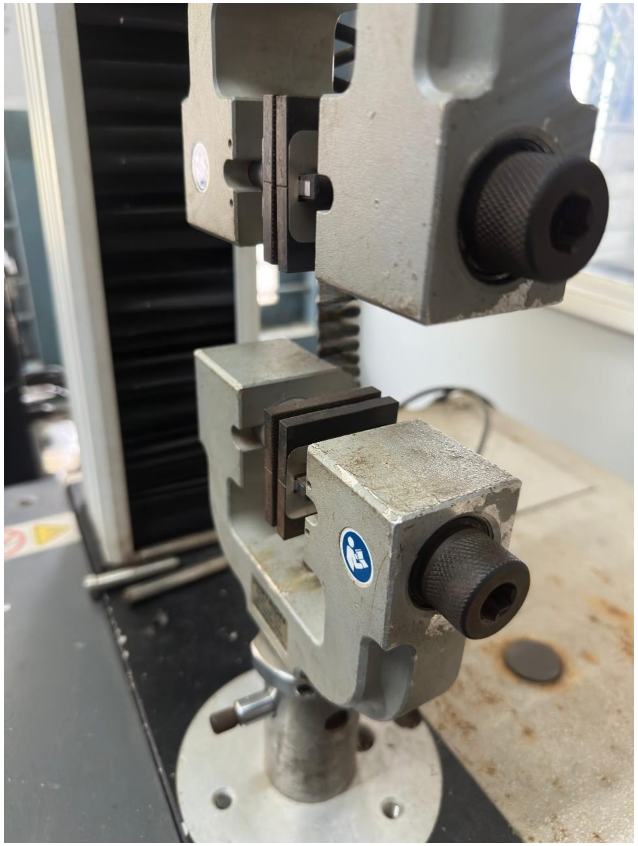
Aim

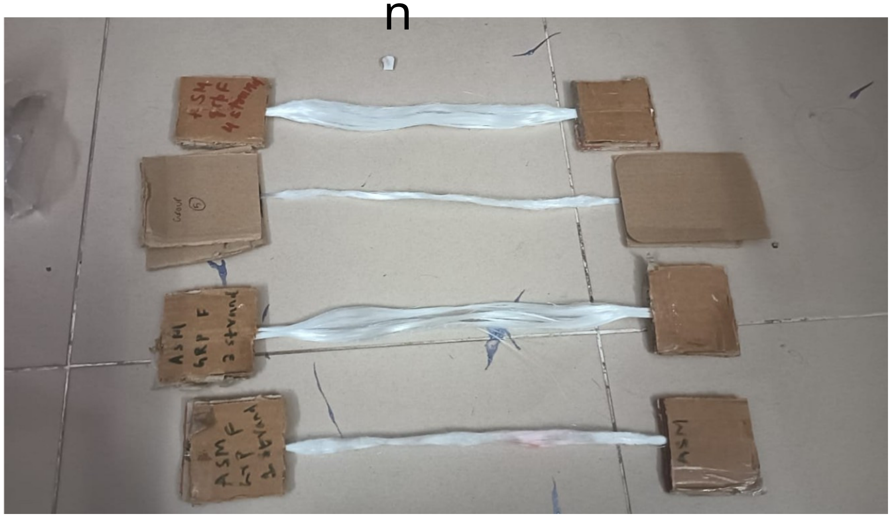
- This experiment aims to analyze how the **tensile failure strength of brittle fibers** varies with **cross-sectional area**.
- This is done using fiber samples of different diameters while maintaining a fixed gauge length.
- The ultimate goal is to understand the **nature of failure** in materials like glass fiber.

Materials Used

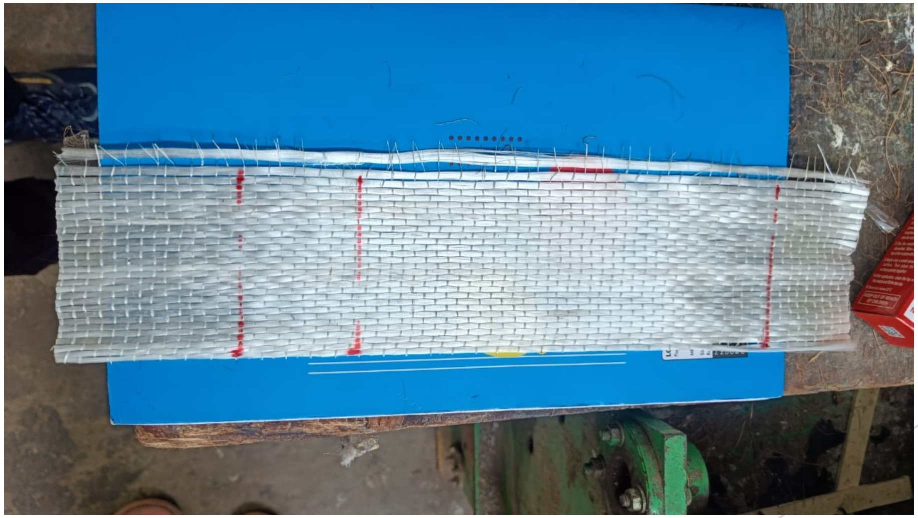
- Universal Testing Machine (UTM)
- EWR 600 Roving Fiber Sheet
- Glass fiber specimens (different diameters)
- Mounting cardboards
- CYNO 777P Adhesive
- Data acquisition software



Specimen



EWR 600 Roving Fiber Sheet



Theory

- Tensile stress (σ) measures resistance to deformation under tensile load.
- Formula: $\sigma = F / A$, where F = applied force, A = cross-sectional area.
- Area of cylindrical fiber: $A = \pi d^2 / 4$
- Threads are assumed cylindrical with a single thread diameter of 0.277 mm. (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 commonly used in practice.)
- Total area increases with more threads.
- As the area increases, the same force is distributed over a larger section
- Hence, stress per thread decreases.
- Brittle materials like glass fibers fail due to microscopic flaws.
- Larger areas increase flaw probability.

Experimental Procedure

- Compute cross-sectional area: $A = \pi d^2 / 4$ using $d = 0.277$ mm.
- Cut threads to 30 cm, designate 5 cm at each end as grip length.
- Attach to cardboard tabs with adhesive.
- Let the adhesive dry to prevent slippage during testing.
- Mount sample on UTM and apply uniaxial tensile load at constant rate of 13 mm /min.
- Record force until the thread breaks, extract max load data.
- Calculate tensile stress at failure: $\sigma = F / A$.
- Repeat for thread bundles of 1 to 5 fibers to assess area dependence.

Calculation

- Diameter, $d = 0.277$ mm $= 2.77\times10^{-4}$ m
- Area, $A = \pi d^2/4 = 6.03\times10^{-8}$ m^2
- Maximum Tensile load for single thread specimen,

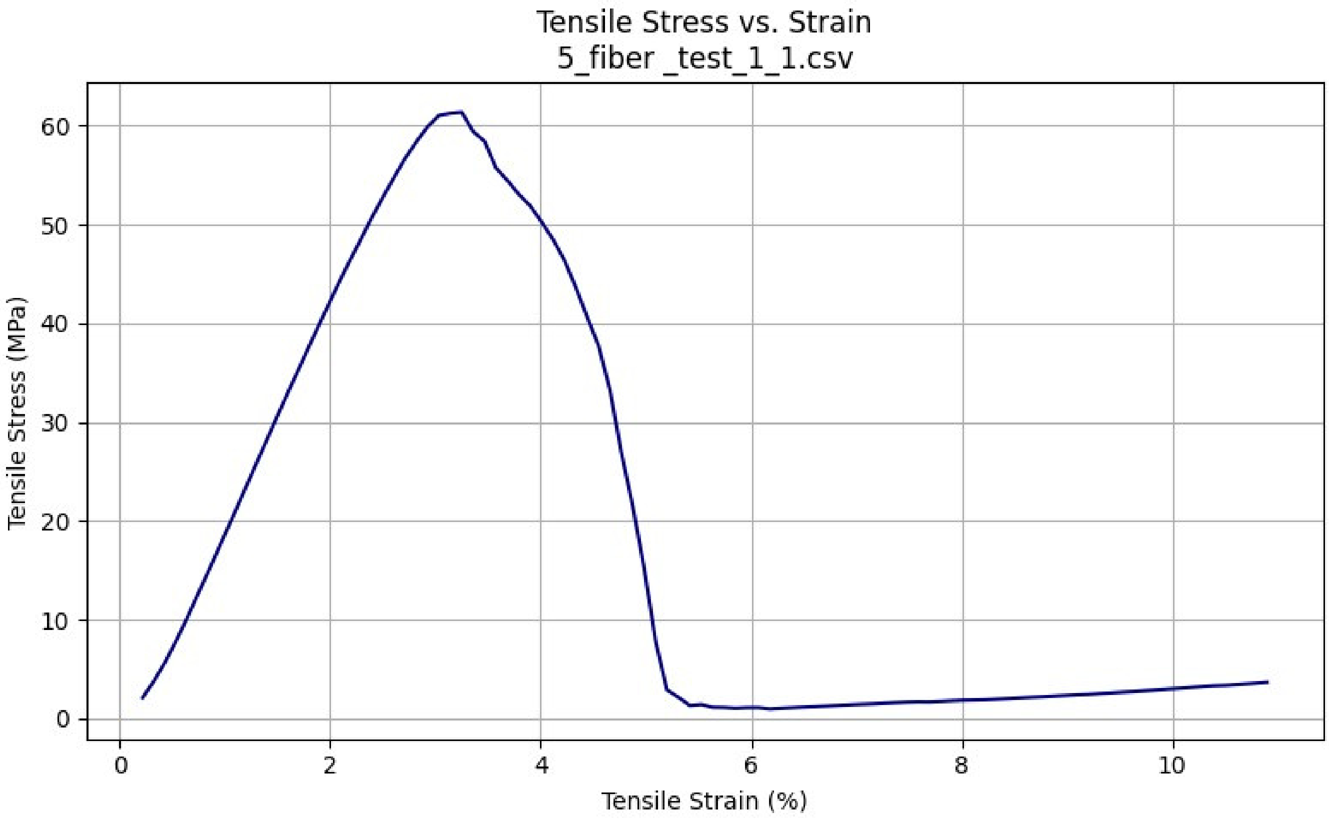
  $F_{max} = 613.5$ N (from data)
- Maximum tensile stress,

  $\sigma_{max} = F/A$

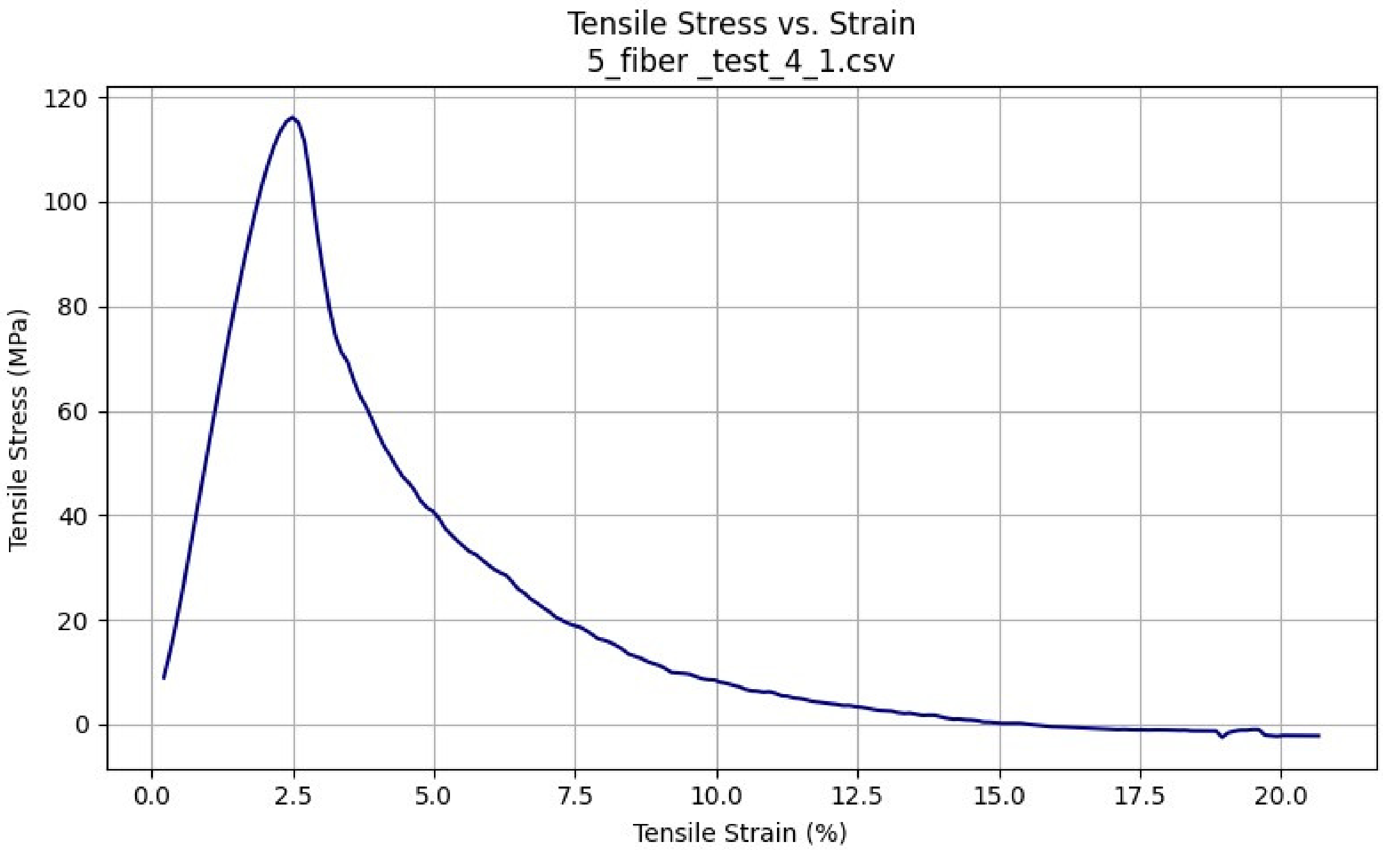
  $= 613.5 / 6.03\times10^{-8} = 10.18$ GPa

Results

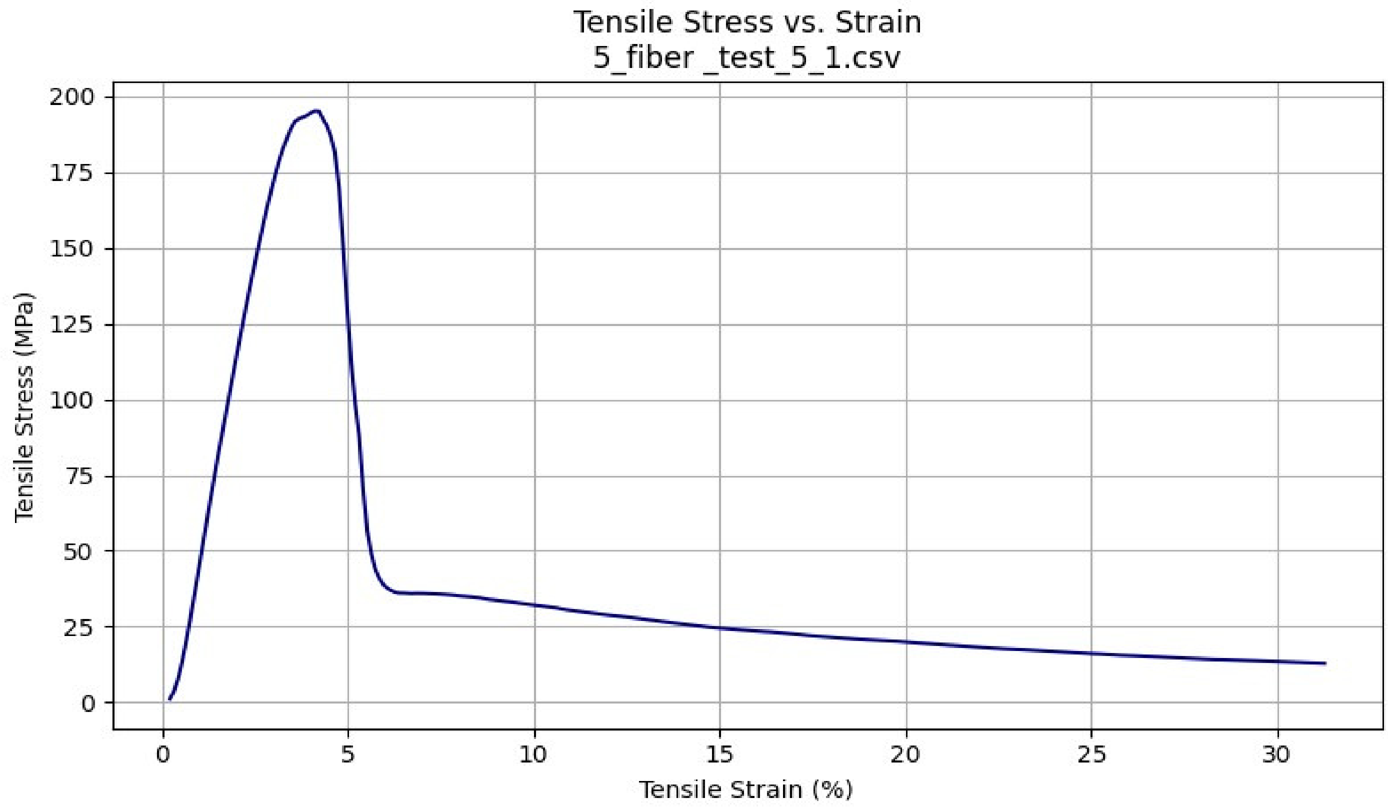
No. of Fibres	Area (mm^2)	Max Stress (GPa)
1	0.0603	10.180
2	0.1210	5.111
3	0.1808	2.141
4	0.2411	2.024
5	0.3013	1.676



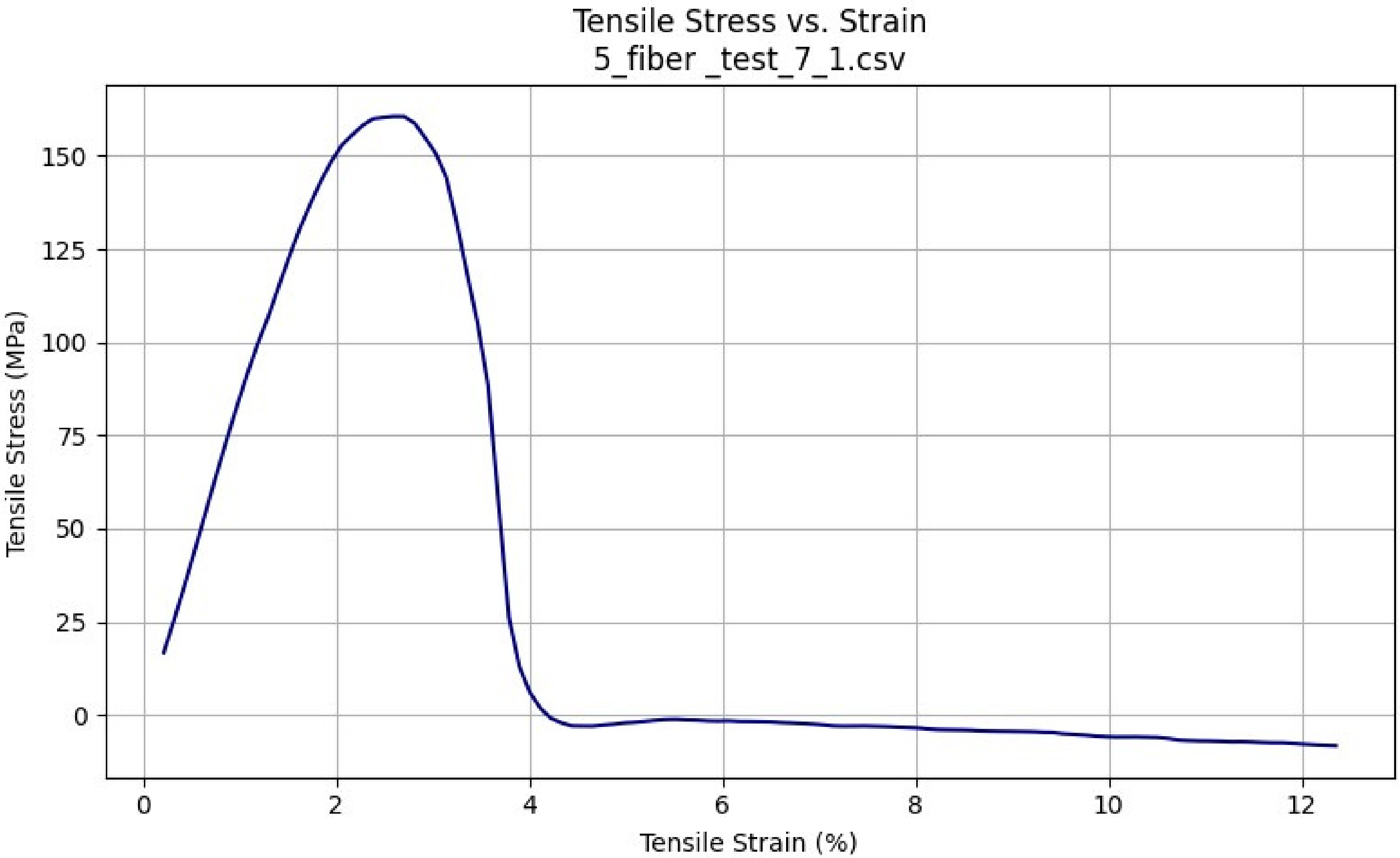
Specimen – 1 thread



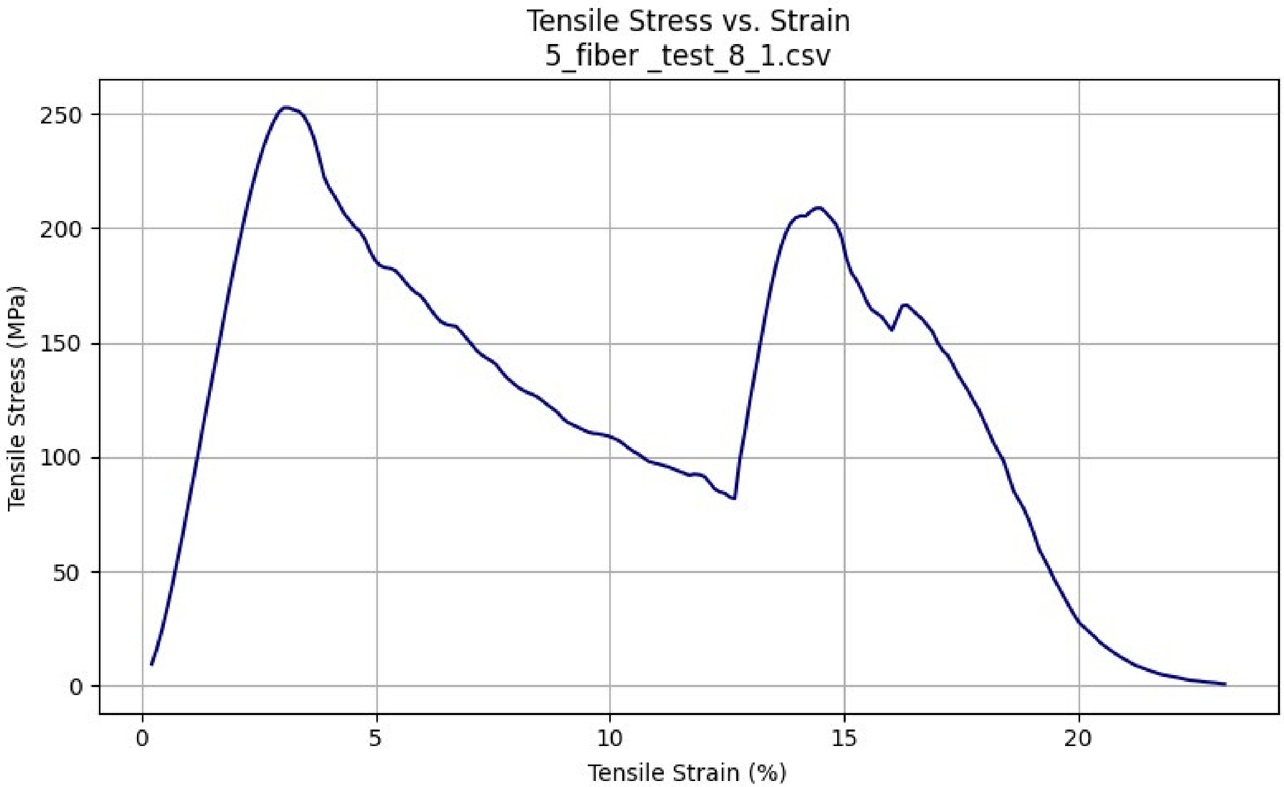
Specimen – 2 threads



Specimen – 3 threads

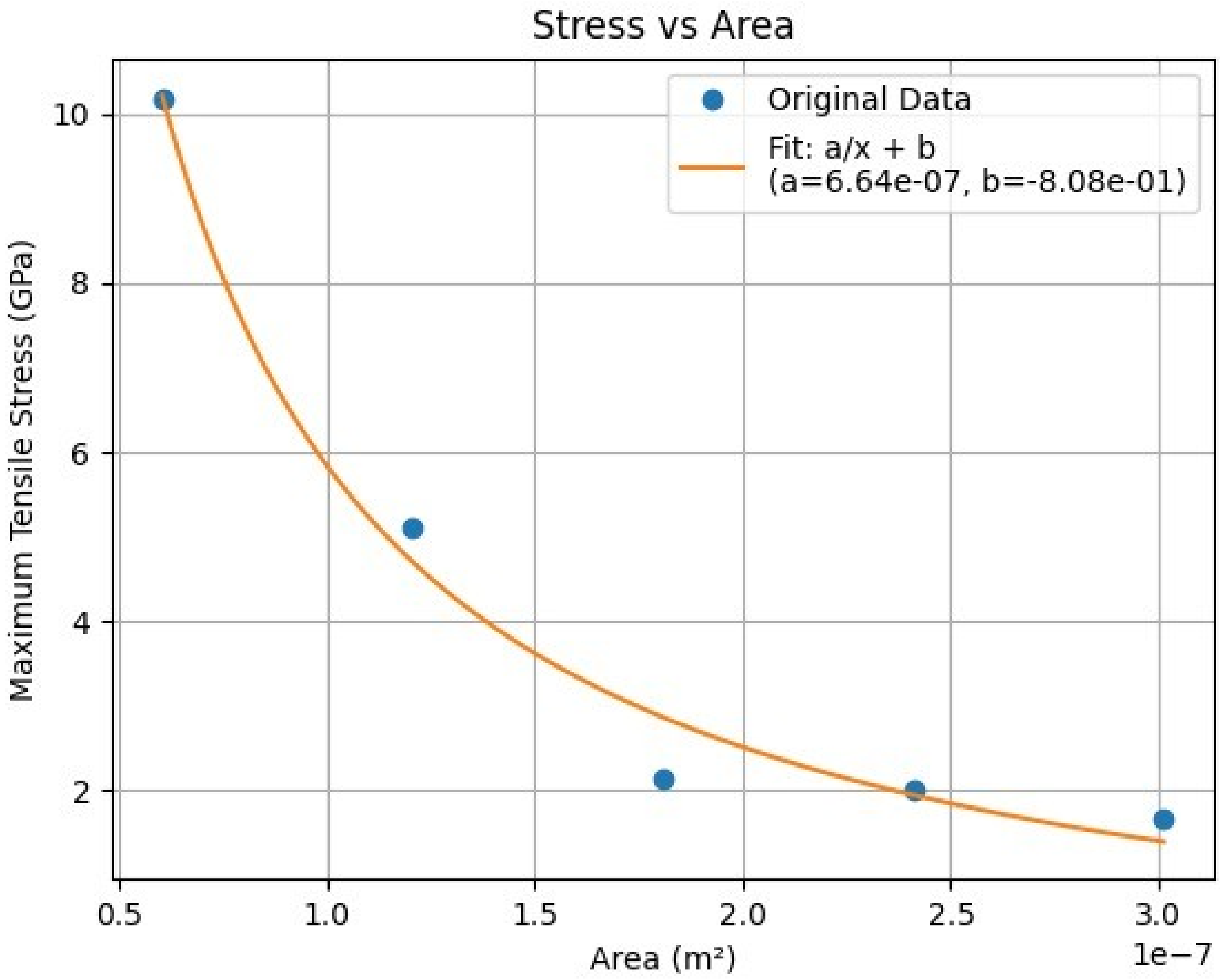


Specimen – 4 threads



Specimen – 5 threads

Load increased in 2nd peak since we applied pressure for preventing the cardboard slipping.



- Plot: **Stress vs. Cross-sectional Area**
- Shape: Approximates a **rectangular hyperbola**
- Indicates stress is inversely proportional to area due to flaw concentration

Observations

- Fibers with a larger cross-section broke more easily, showing that thicker fibers are more likely to have tiny defects that cause them to fail.
- As area of cross-section increases, the maximum tensile stress decreases.

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.

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.

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