HEMP FIBER REINFORCEMENT OF WOOD - SODIUM SILICATE COMPOSITES

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OBJECTIVES

Hemp fibers are known to have high tensile properties and are biodegradable. They have been successfully used as reinforcement materials in polymer composites by improving the mechanical properties. The objective of this research is to study the effect of hemp fiber reinforcement on the extrusion process and the mechanical properties of wood – sodium silicate composites;

- Continuous fiber extrusion
  Develop a process for feeding a single strand of hemp fiber into a composite matrix.
- Chopped fiber extrusion
  Study the parameters for hemp fiber reinforcement, such as fiber length, fiber amount to optimize the extrusion process and improve the mechanical properties of the composite.

FIBER CHARACTERIZATION

Hemp fiber diameter measurement

Hemp fiber diameter was measured using an optical microscope (5X to 20X magnification). Hemp fiber diameter varies greatly, even within a strand and has splits and branches (as shown in figure).

Most fibers have a diameter between 50 and 150µm.

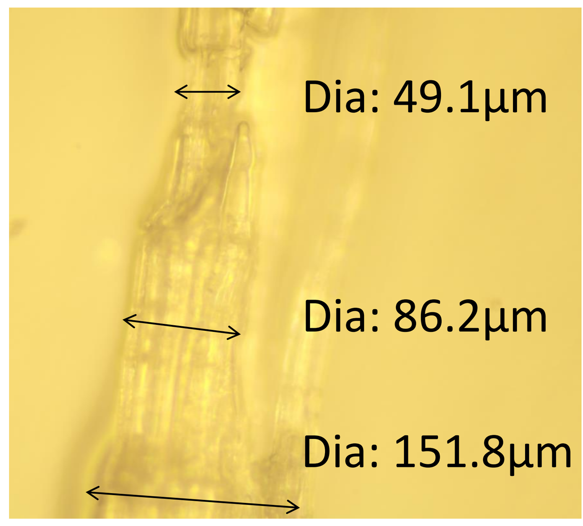

Figure 1: 20X microscopic image of hemp fiber

Fiber tensile testing

Individual fibers were tested for tensile strength using DMA. Average tensile strength of hemp fiber was 826MPa.

Due to the small diameter of hemp fibers, the breaking force was only about 2-3N, which lead to many fibers being damaged while handling, specially when placing the fiber in the grips and tightening the screw.

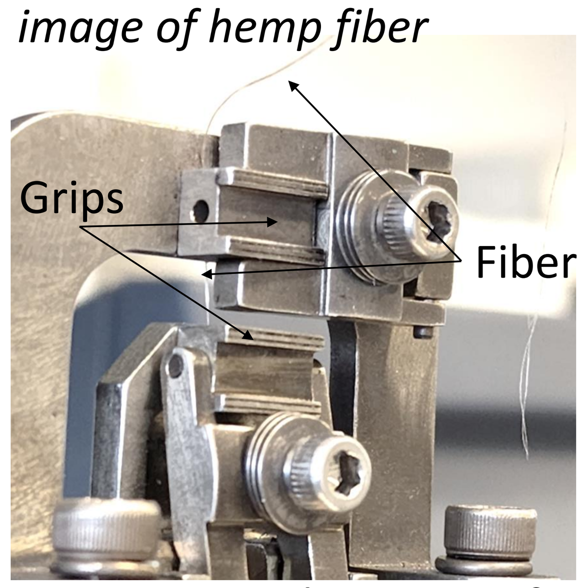

Figure 2: Tensile testing of hemp fiber

Future work

Further fiber characterization would involve testing the interfacial shear strength of fiber-resin bond. This is commonly done using by a single fiber pullout test.

A single drop of resin (sodium silicate) is added on a fiber (as shown in figure). The composite is then placed in the tensile testing grip (with an opening equal to the fiber diameter) such that the fiber is pulled out of the resin.

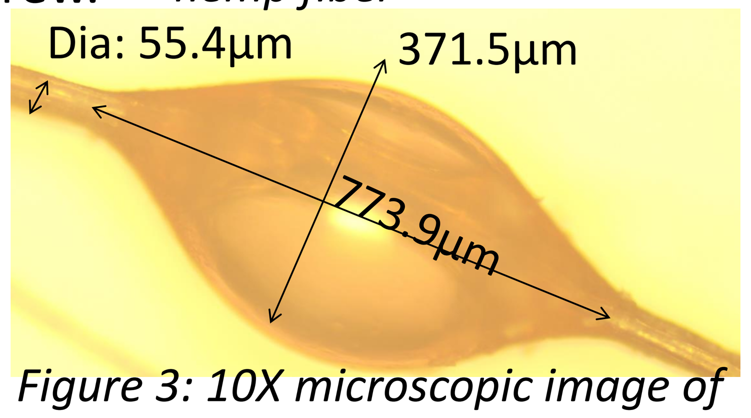

Figure 3: 10X microscopic image of sodium silicate drop on Hemp fiber

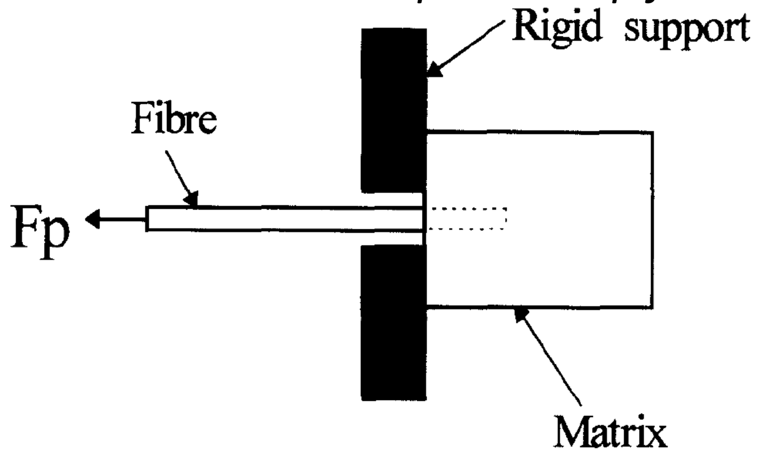

Figure 4: Single fiber pullout test

CONTINUOUS FIBER EXPERIMENTATION

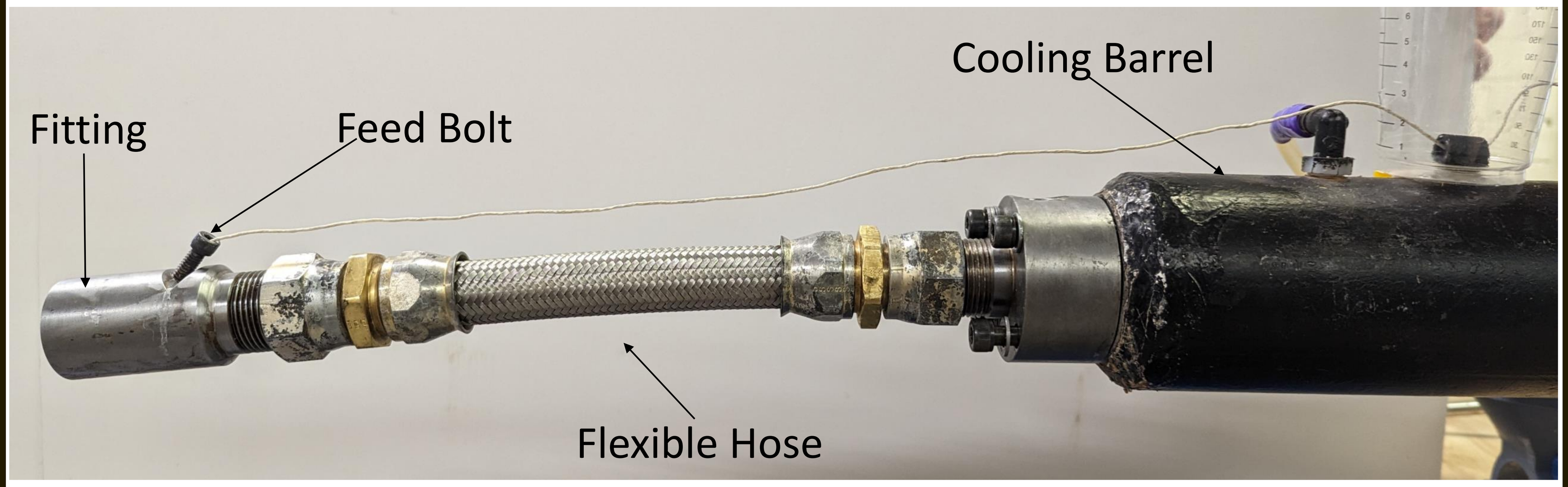

Figure 5: Schematic for the mechanism to 3D print continuous hemp reinforced wood-sodium silicate composites.

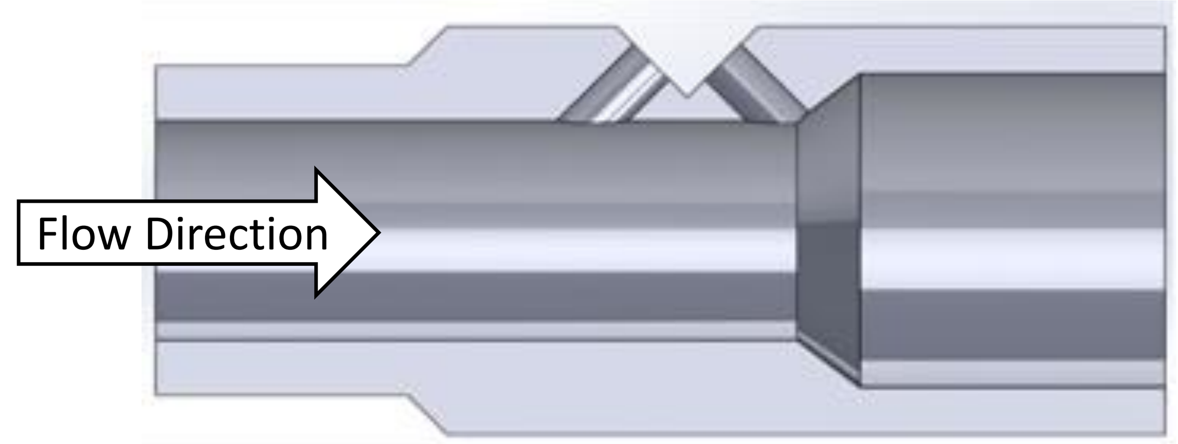

Figure 6: SOLIDWORKS section view of the fitting made to feed the Hemp twine

Modifications to Fitting for Hemp extrusion

Two bolt holes so that it can print with flow going either direction. Threaded for ¼-20 1inch long bolts so that if clogged they can be replaced.

Twine pretreatments

Sodium silicate immersion reduced the friction between the string and matrix and stopped the twine from being pulled along.

Water immersion helped to reduce the pressure buildup in the system and allowed the string to be extruded right on center.

Bending and compressive strength tests

Sample ID*	Bending strength (MPa)	Young's modulus (MPa)
D1	20.30	2099.57
D2a	18.87	2104.10
D2b	17.61	1802.87
D avg.	18.92	2002.18
N1	21.39	2255.17
N2a	25.68	2222.30
N2b	19.61	2292.64
N3a	21.05	2070.21
N3b	21.50	2124.41
N avg.	21.85	2192.95

Sample ID*	Compressive strength (MPa)	Modulus (MPa)
D1a	20.30	1447.18
D1b	20.50	1535.53
D2a	17.64	1386.58
D2b	20.33	1713.92
D2c	20.62	1696.42
D avg.	19.78	1555.926
N1a	24.88	1857.19
N1b	22.29	2016.51
N1c	25.15	2224.21
N1d	24.76	2197.08
N2	24.02	2093.46
N3a	19.12	1663.43
N3b	16.72	1411.09
N avg.	22.42	1923.28

Future work

Currently the only strength tests that were performed were only done on replicates that were cured under one condition, cured for 5 days at 105C. Previous research shows that high temp curing may have adverse effects on strength.

CHOPPED FIBER EXPERIMENTATION

Preparation of samples

Hemp fibers were chopped to a length of approximately 5mm using a paper cutter and a 3D printed jig.

The cut fibers were mixed with wood and sodium silicate with the following ratio:

2% Hemp fiber

48% Wood fibers

50% Sodium silicate

Specimens of 16" were extruded to machine one bending and 2-3 compression specimens for testing.

The specimens did not extrude evenly, and sharkskin was observed.

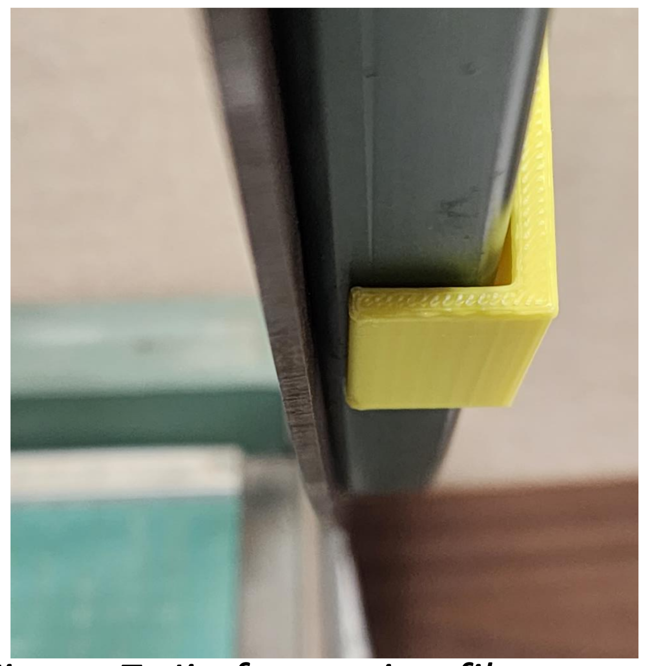

Figure 7: Jig for cutting fibers

Figure 8: Compression test

Bending and compression tests

Average bending strength of the 3 specimens tested was 12.1MPa.

Bending strength with continuous fiber was observed to be 21.85MPa and strength of Wood Sodium Silicate Composites was between 23 and 25MPa.

Average compression strength of the specimens was 11.6MPa.

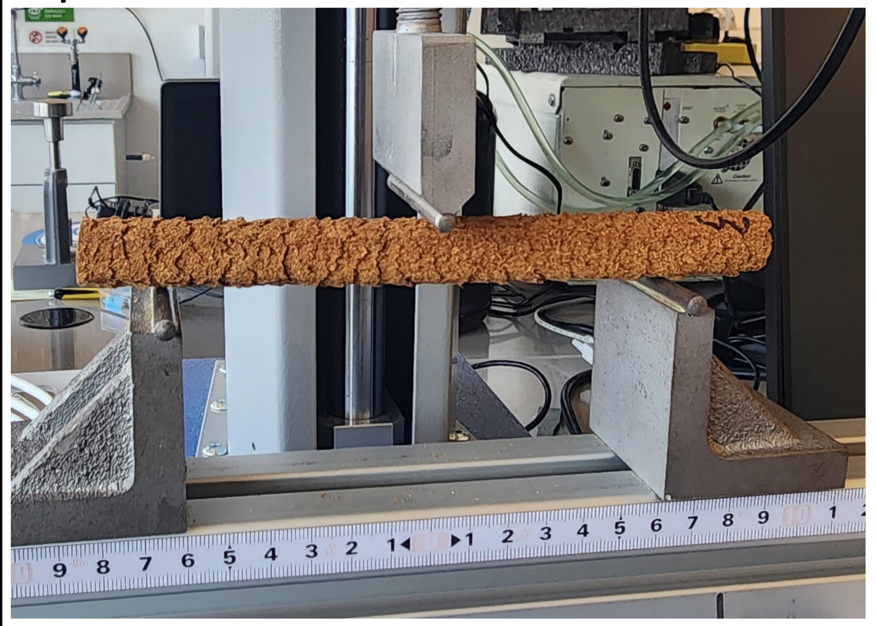

Figure 9: Bending test showing sharkskin on specimen

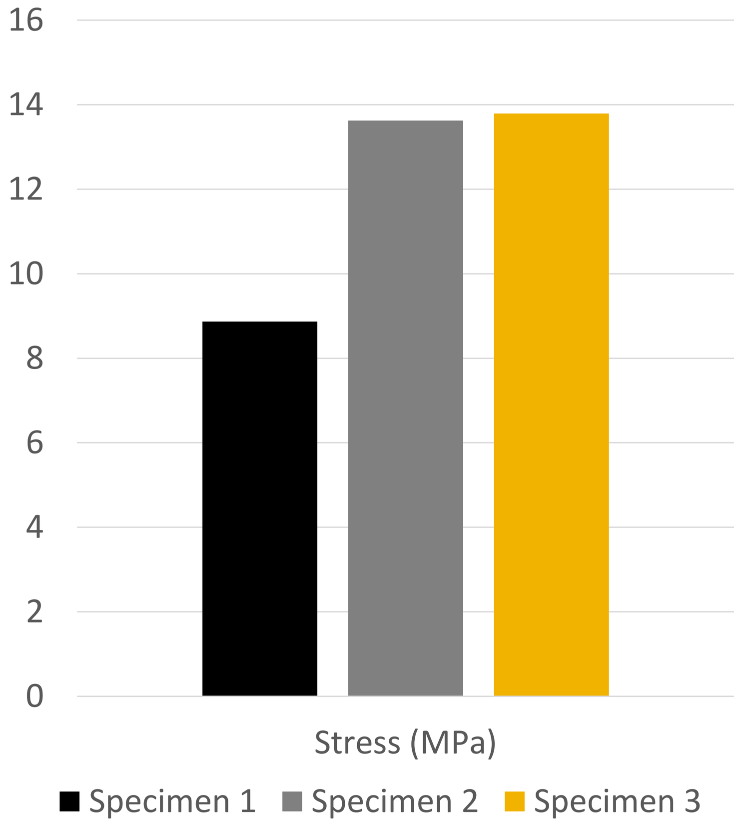

Figure 10: Bending test result

Future work

Further extrusion with varying compositions from 1% to 20% Hemp fibers. Change of composition of sodium silicate and mixing process may also be required to reduce sharkskin in the extrudate.

ACKNOWLEDGEMENTS

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