CAAP Annual Report

Date of Report: *July 7, 2020*

Contract Number: *693JK31850009CAAP*

Prepared for: *U.S. DOT Pipeline and Hazardous Materials Safety Administration*

Project Title: New Bio-Inspired 3D Printing Functionalized Lattice Composites for Actively Preventing and Mitigating Internal Corrosion

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For quarterly period ending: *July 7, 2020*

Business and Activity Section

(a) Generated Commitments

No-cost extension will be made to the existing agreement

Purchase made for the nano-materials, and the pump related supply

(b) Status Update of Past Quarter Activities

The research activities in the 7th quarter report aimed to complete research activities in Task 2, and continuing efforts on Task 6.

(c) Cost share activity

Cost share was from the graduate students' tuition waiver.

(d) Summary of detailed work for Tasks 2, and 6

Task 2: Fabricate, Characterize and Optimize 3D printing lattice composites

A comprehensive and systematic study of new 3D printing lattice composites was conducted for characterizing their mechanical and chemical properties.

Among them, we missed the tensile property of the lattice structures. We reported our early attempt on early document on the tensile test by mounting metal sheet at back of the samples, but most samples failed by locally interfacial bond, which did not help to generate accurate tensile property of the lattice. Thus, another attempt was made to perform the direct tensile test to complement the test matrix in this period.

2.2.1 Tensile properties of 3D printing lattice structures

2.2.1.1 Sample preparation for macro-scale tensile test

This section aimed to understand tensile behavior of the 3D printing lattice members. We used the PLA purchased from Hatchbox to print the specimens. The specimens were drawn in Rhino 6 and using custom VB Scripts first the toolpaths were generated and then the G-codes were generated for each specimen, as shown in **Fig. 1**. For every print, the parameters were kept constant. The bed temperature was 70° C and the nozzle temperature was 205° C for each print. The specimens have an outer dimension of 5.0 mm diameter and 72 mm height. They were printed in a vertical way to have each layer of the filter in horizontal order.

Fig. 1. Generated G-code of the specimens using Rhino6, LS type (Left), R type (right)

2.2.1.2 Test setup

Mechanical properties of 3D printing samples, i.e., tensile strength and tensile behavior in macro scale, was characterized using an Instron 5882 universal testing machine, as shown in **Fig. 2**. The 3D printing samples were selected with pore size of 0.4-, 0.6-, and 0.8-mm for both LS and R types.

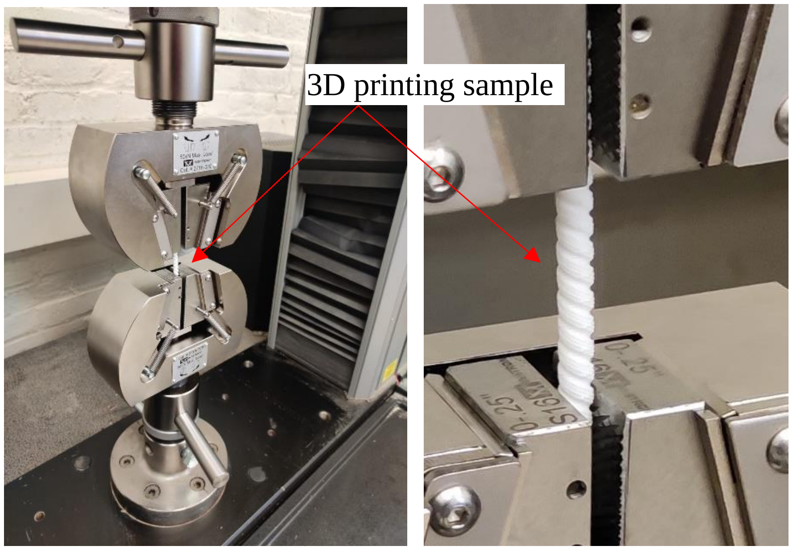
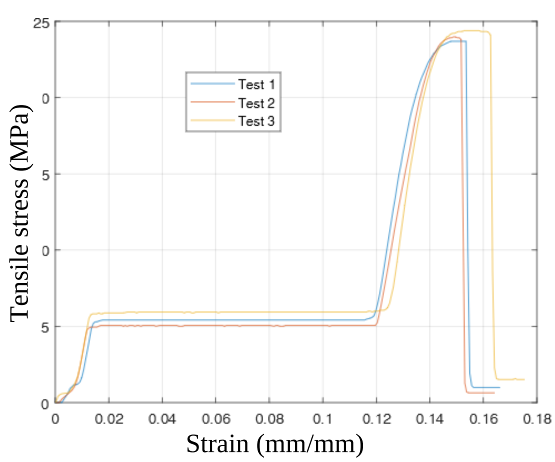


Fig. 2. Test setup

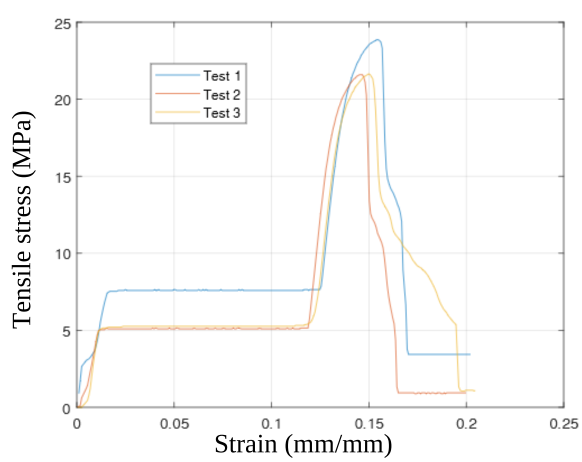
2.2.1.3 Test results and discussion

The tensile property of the 3D printing lattice structures was plotted in **Figs. 3(a)-3(f)**. Similar trend to their compression was observed on tensile stress-strain relation through three stages were observed: (a) pre-yielding; (b) plateau; and (c) post strain-hardening behavior.

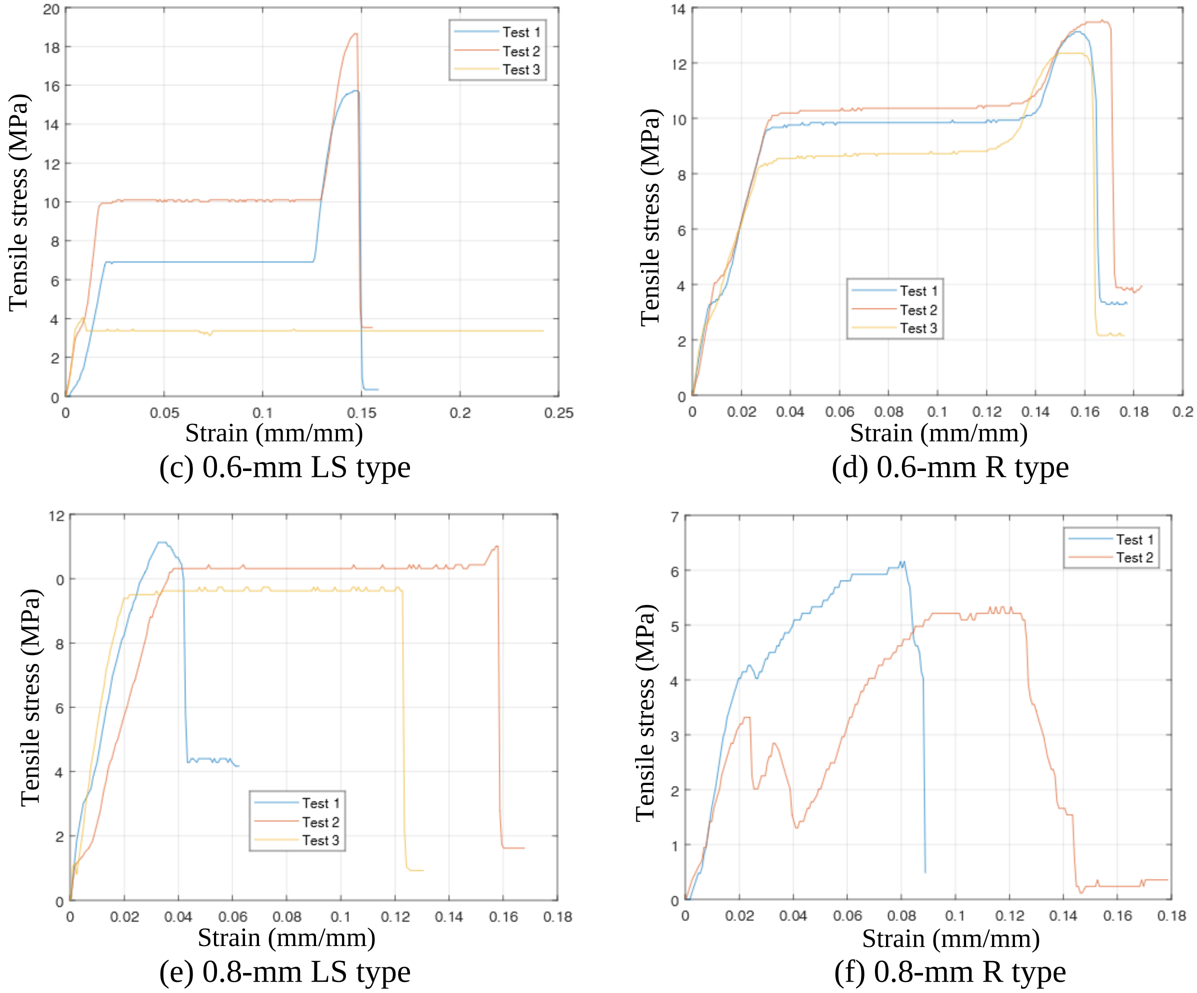
As illustrated in **Figs. 3(a)-3(f)**, before yielded, all lattices behaved nearly linear. Clearly, 0.4-mm and 0.6-mm LS/R patterned lattice samples started to yield about 5.0~10.0 MPa. After that, the lattice exhibited a long plateau, and then quickly displayed a strain-hardening/necking behavior due to polymer permanent deformation. However, with the pore size increase, as illustrated in **Figs. 3(e)-3(f)**, 0.8-mm LS/R patterned lattice samples showed different behavior, where LS type samples had no apparent strain-hardening behavior (see **Fig. 3(e)**), and R patterned lattice started strain hardening behavior just after yielding (see **Fig. 3(f)**), without plateau as other cases did.



(a) 0.4-mm LS type



(b) 0.4-mm R type



(c) 0.6-mm LS type (d) 0.6-mm R type

(e) 0.8-mm LS type (f) 0.8-mm R type

Fig. 3. Tensile stress-strain curve for both LS/R type samples

Task 6: Assess long-term durability tests of the new composite systems

As we discussed at last report, the attempts were made to increase the applications of the designed lattice structures for accommodating pipe environment. This study will continue this effort to provide a concept design using a pump system and elucidate the critical design parameters for Task 8.

The initial test set up was assembled in detail for calibrating the design concept. The syringe pump machine was from the standardized KD Scientific. The machine allows for a variable and/or constant infuse/withdraw flow rate and force rate to provide for precise flow volume moved throughout the attached flow system, as typically shown in **Fig. 4**.

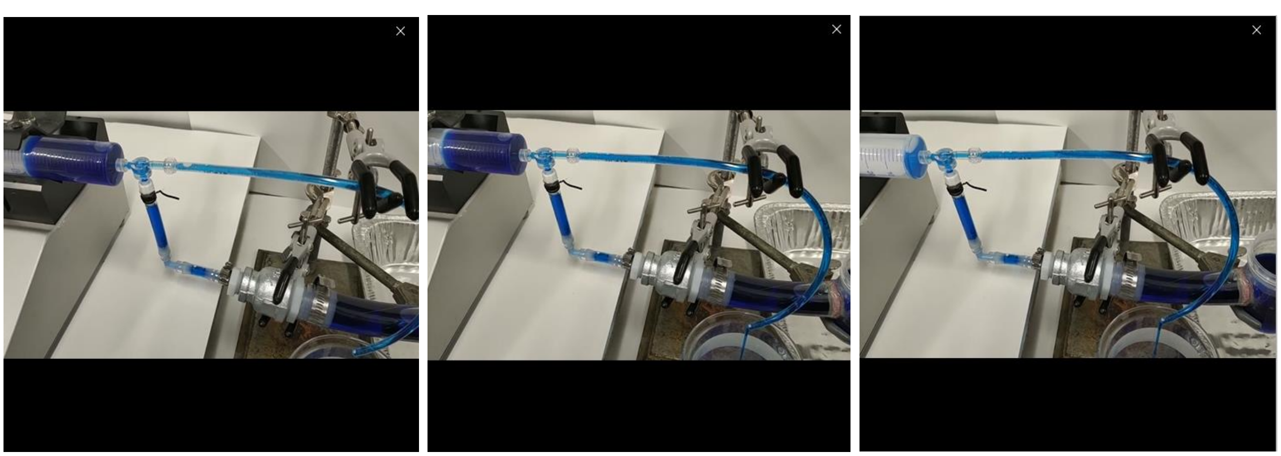


Fig. 4 Snapshot of extraction process of water

6.3.1 3D printing ring sample design (no sample print yet in this period)

Basic 3D printing ring samples were designed and generated in SolidWorks. Following up the initial design, illustrated in **Fig. 5**, samples will be categorized in LS-patterned and R-patterned types.

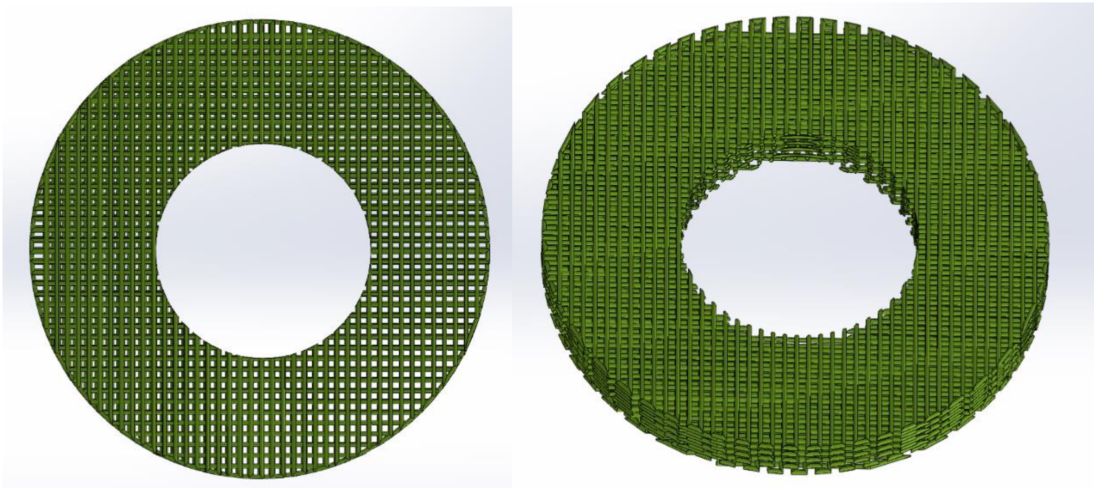


Fig. 5 Ring sample design

(e) Description of any Problems/Challenges

No problems are experienced during this report period

(f) Planned Activities for the Next Quarter

The planned activities for next quarter are listed below:

- More efforts on investigation of the effectiveness of 3D printing lattice structures under the new designed pump system, and understanding of pump-induced pressure and flow behavior.
- Continuing efforts on characterization of durability of all-in-one heterogenous stacked layers.
- New efforts on the 3D printing ring sample design and optimization.