Printing of Thermoset Elastomer Compounds

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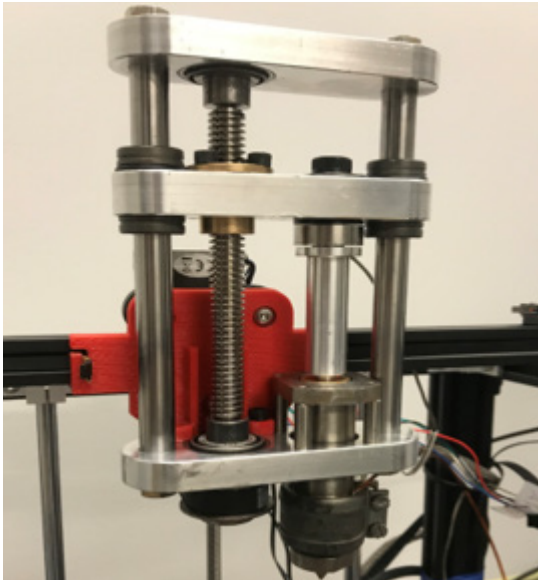
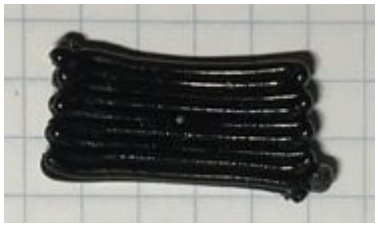
There currently exist a variety of methods for industry to 3D print thermoplastics, metals, and thermoplastics elastomers. A gap remains for a robust method to 3D print a fully compounded thermoset rubber material. The advantages of fully compounded elastomers include high flexibility, elastic recovery, high elongation, and heat and solvent resistance. One of the key challenges in 3D printing a highly flexible materials is passing it through the typical roller system continuously as these materials tend to deform and cannot pass through the nozzle. Another challenge is to control the process such that the materials do not cure prior to printing the desired structure. With the goal to start with a commercially available fused filament fabrication (FFF) printer, a Creality Ender 5, with a stiff x-y system and open printing bed was chosen. In order to overcome the challenges of feeding such a flexible and viscous material, a ram type system was designed. The Additive Ram Material Extruder (ARME) was the final design, which was prototyped, assembled, mounted on the FFF Printer. The ARME has a maximum crosshead load of 1500 lb (3300 psi) and provides positive volumetric output for rubber deposition. Initially a thermoplastic elastomer was tested with great success. From those learnings, polyisoprene and nitrile rubber (NBR), a copolymer of acrylonitrile and butadiene, were both tested without the curative. Nitrile rubber (NBR) with a sulfur cure system was chosen for printing. Materials with and without carbon black were successfully printed into multi-layer shapes using the ARME. The effect of temperature on cure time was evaluated to predict appropriate printer temperatures and post printing cure parameters. This project also gained insight into the viscosities and temperature and time before cure, needed to determine system requirements for a rubber 3D print system. Good adhesion between subsequent roads was found. This technology has the potential to enable industry to print complex rubber products, such as gaskets, shoe soles, medical devices, and components for soft robotics.



The assembly of the Additive Ram Material Extruder (ARME) printer assembled to the Ender 5 printer.



An ARME 3D printed sample of 28% acrylonitrile nitrile rubber (NBR) with 30 phr of carbon black.