Group 18
Running Blade
(Data and Pictures of FEA, Instron Tests, and Solidworks located in 'ME10 Final Project – Data & Pictures')

For our final project, we decided to create a scaled version of a prosthetic running blade like the ones that are seen on athletes who are missing portions of their legs. Our inspiration for doing this came from our desire to create something to do with the human body—the sleek, simple design of the prosthetic fits this perfectly.

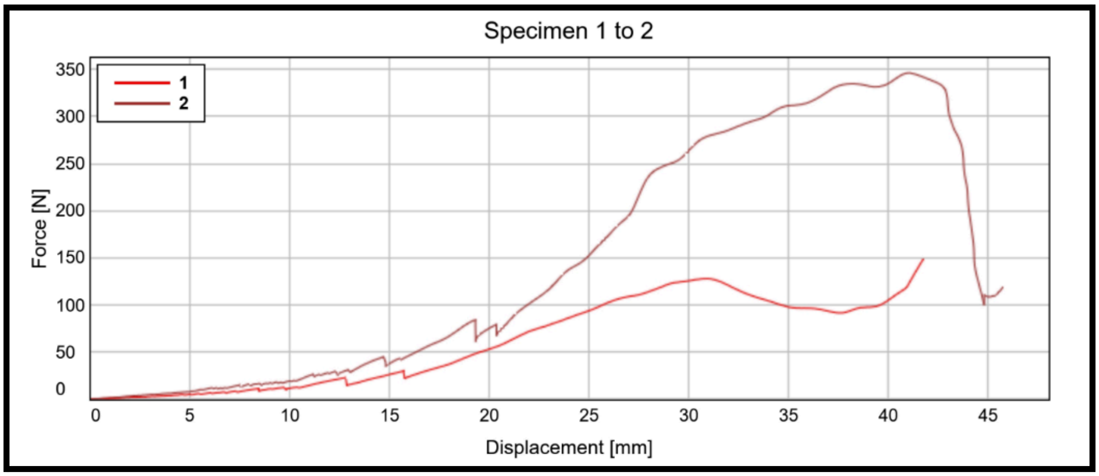
In reality, prosthetic running blades are composed mostly of layers of carbon fiber prepreg. The main advantage of using carbon fiber in an application like this is its incredible strength-to-weight ratio. This provides a rigid blade that will be able to support the intense loads of striking the ground without hindering the athlete. Obviously, making a true-to-form running blade would not be possible within the project scope, but with the facilities provided at Bray Laboratory, we were able to produce a running blade that had an element of carbon fiber infused into it. This was made possible by the Markforged 3D printers and the Markforged composite material, Onyx.

Onyx isn't a typical 3D printing material due to the fact that it isn't a standard plastic. Rather, Onyx is a composite material that consists of nylon and, most importantly, carbon fiber pellets. Due to the nature of carbon fiber in pellet form as opposed to continuous strands, we expected the material to act differently from the carbon fiber that is seen in industry. However, the mere addition of carbon fiber to a printable material makes it far stronger than a pure polymer. With this in mind, we wanted to determine the true effect of printable carbon fiber on 3D printing materials. We achieved this in two different ways: finite element analysis and compressive testing using the Instron machine.

To create our FEA, we first had to create materials to apply to our modeled running blade. Using material properties provided by Markforged's own Onyx data sheets, we produced an accurate material on Solidworks that mimicked the behavior of Onyx plastic. Then, we applied a fixture to the top of our running blade and applied loads from the 'ground' to the bottom of the blade's surface. We then ran and obtained data from our FEA. One point to note about our FEA simulation is the presence of large deflections during the simulation. This makes the small displacement assumptions that typically run through FEA simulations invalid. To counteract this, we ran the simulation with a piece-wise approach. This inherently makes the data less accurate, which in turn can produce more discrepancies when compared to the Instron test.

To produce our tests using the Instron machine, we deemed it fit to place the top of the running blade in a wedge grip to support it during the test while the bottom was left unsupported. We then ran the Instron machine under a compressive test, which slowly brought the load cell downward, thus applying compressive force to the bottom of the running blade. We modeled both tests to stop after an 80% reduction in load was experienced. However, before we could reach that point, the running blade's 'toe' deflected upwards and hit the wedge grip. We deemed this to compromise the data and therefore stopped testing after that point. Another point to consider is the presence of small drops in the graph for both materials. This is due to the material slipping as the load increased. Initially, the point of contact between the running blade and the surface was not aligned with the force applied by the load cell. As more load was applied, the point of contact between the running blade and the ‘floor’ became more oriented with the force of the load cell, which in turn decreased the frequency of slipping.

The instron tests yielded some interesting results, and we can extract information just by looking at the stress-strain curves: (The Onyx blade is curve 2 and the PLA is curve 1.)



Both curves have a non-linear elastic region that is characteristic of polymers, but the PLA curve looks more like a thermoplastic because of the increase in strength after yielding. Although nylon is also a thermoplastic, the carbon fiber makes it *more than twice* as strong and also affects the behavior of the material after yielding, which gives it a shape similar to a ductile metal (obviously with much lower strength).

The deformation of the running blade during testing also looked very similar to our FEA simulations. Something that could be improved is figuring out how to run a dynamic simulation of the running blade to analyze how it performs in actual running conditions. Due to the fact that polymers react very differently to the rate at which a load is applied, we expect results and material behavior would be very different. Our static FEA provides a good baseline though, and recreates the experimental deformation well.