

High Temperature Cast Iron Materials for Exhaust Components

Team 20: Caterpillar MET / MSE Partnership

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Problem Statement

Caterpillar and Purdue Material Science Engineering required SOET to produce 5–1 SiMo ductile iron for metallurgical and mechanical testing. The casting process must use the CAT Smart Foundry in Lambertus and student designed foundry tooling in addition to processes. Throughout the project, students must control pouring conditions, cooling rates, melt chemistry, and safety. Producing reliable samples allows MSE to complete material characterization and support evaluation of this alloy for high-temperature engine components.

Customer Background

Caterpillar Inc. is a global leader in the earthmoving, construction, marine, and power generation markets, producing equipment that operate in extreme conditions. Current high silicon-molybdenum (SiMo) alloys face performance limitations in environments characterized by elevated temperatures, severe corrosion, and intense thermal cycling. This project uses the Caterpillar Smart Foundry to develop a student-designed alloy engineered to exceed the performance of traditional SiMo alloys, ensuring greater durability for engine and power generation components.

Requirements

- Produce 5-1 SiMo ductile iron
- Design and manufacture tooling for the castings
- Cast test bars that can be used for tensile tests and micrograph analysis
- Utilize Sinto FDNX flaskless green sand molding machine
- Acquire and modify foundry equipment so ductile iron can be safely poured
- Develop standard operating procedures for foundry

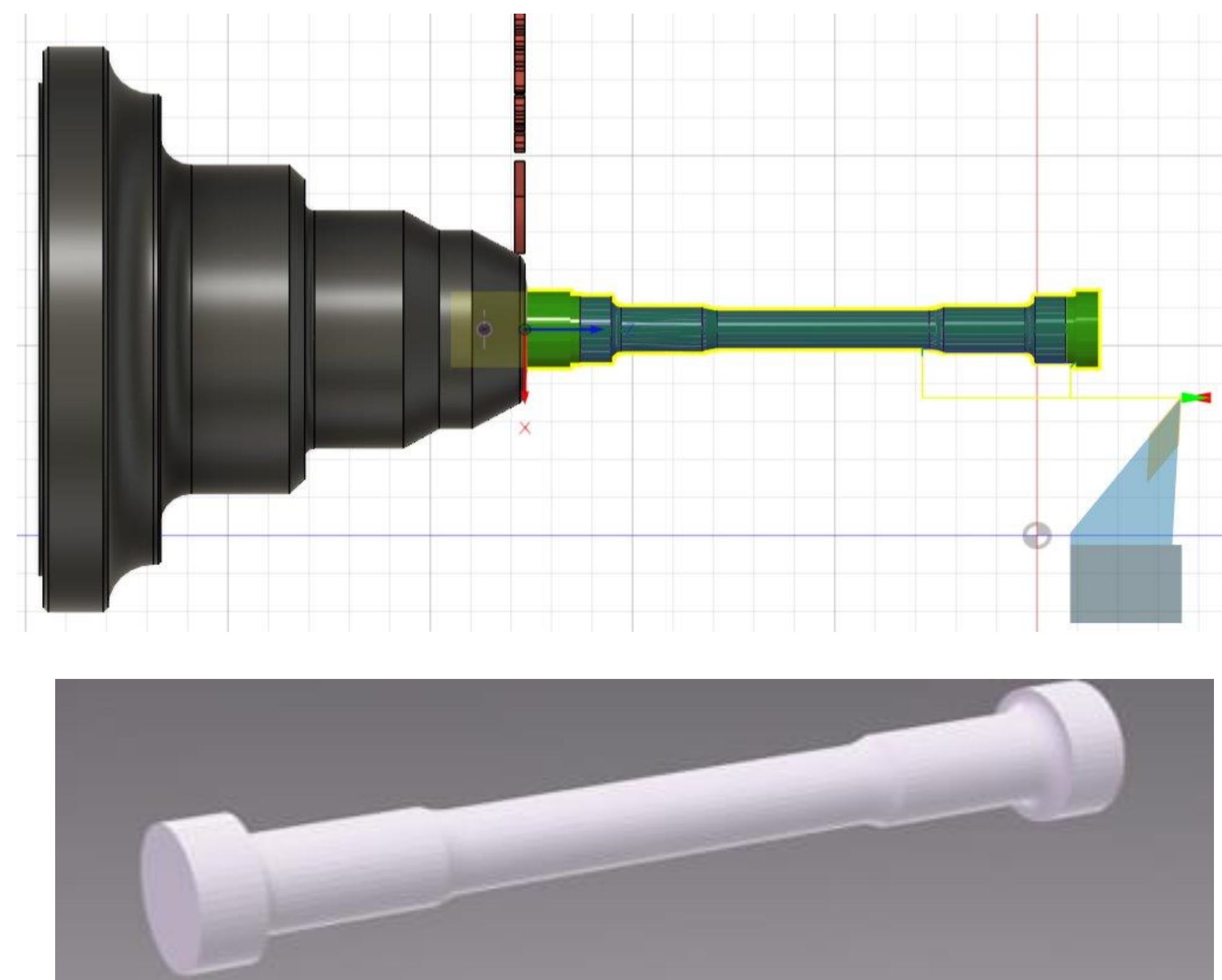


Experimentation and Concepts

It is important for the runner/gating to be specially designed for quality castings. The runner has steps, with each step reducing the runner's cross-sectional area by the area of the gate. This allows for the flow rate and velocity to remain constant as the bars fill. The areas are also designed so that the fluid velocity is slow enough to prevent turbulence.

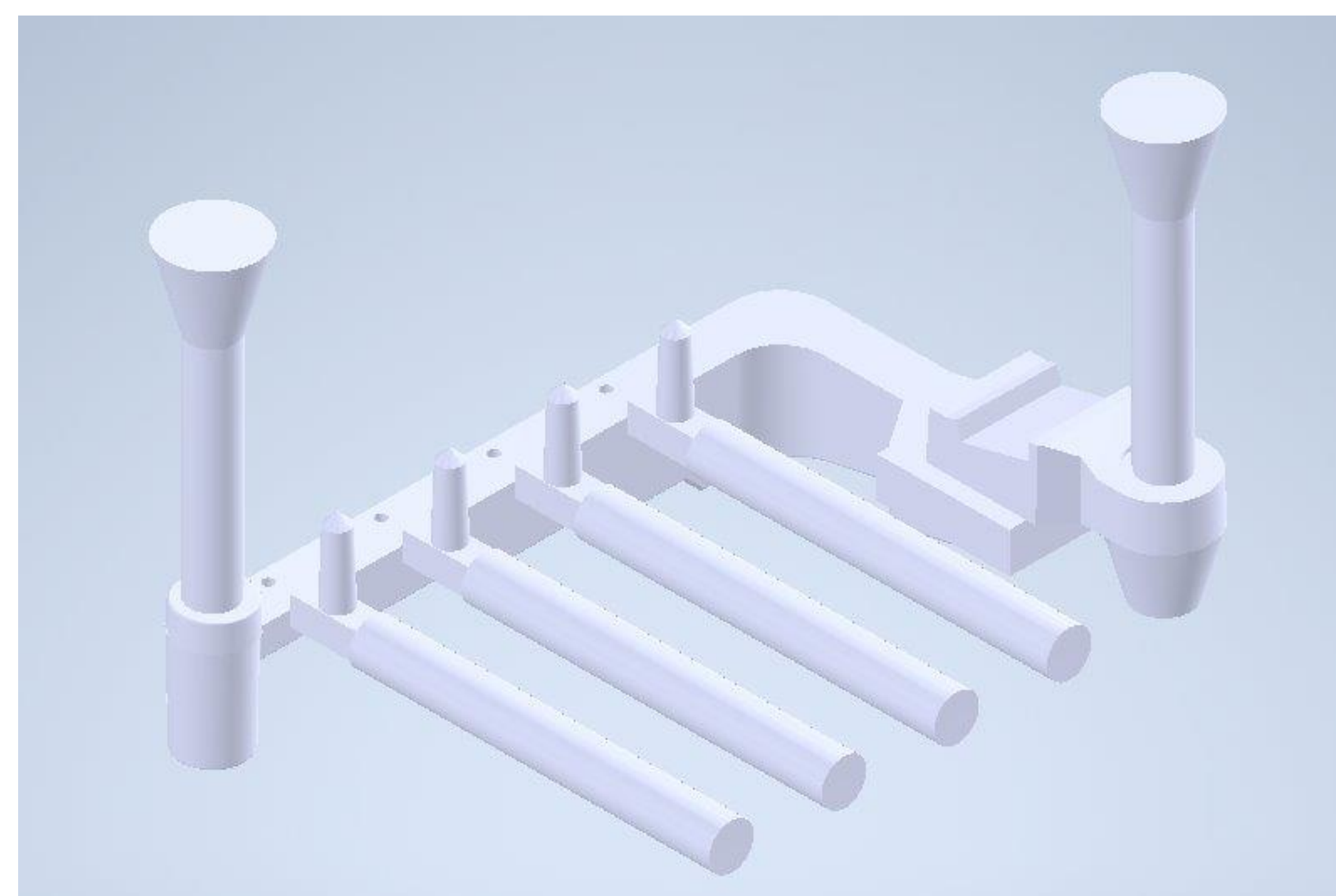
To make ductile iron, the carbon must be made into a spherical shape compared to flake graphite. This is achieved through nodularization using a ferromagnesium additive. Temperature and other process parameters must be controlled to ensure the formation of spherical graphite.

We created a CAD model of a CAT specified UTM bar spec. Due to the need of precise repeatability, we decided to use a CNC lathe. We created a program that would be used on an ST-20. Due to the lack of remaining time in the year, we were unable to machine the bar.



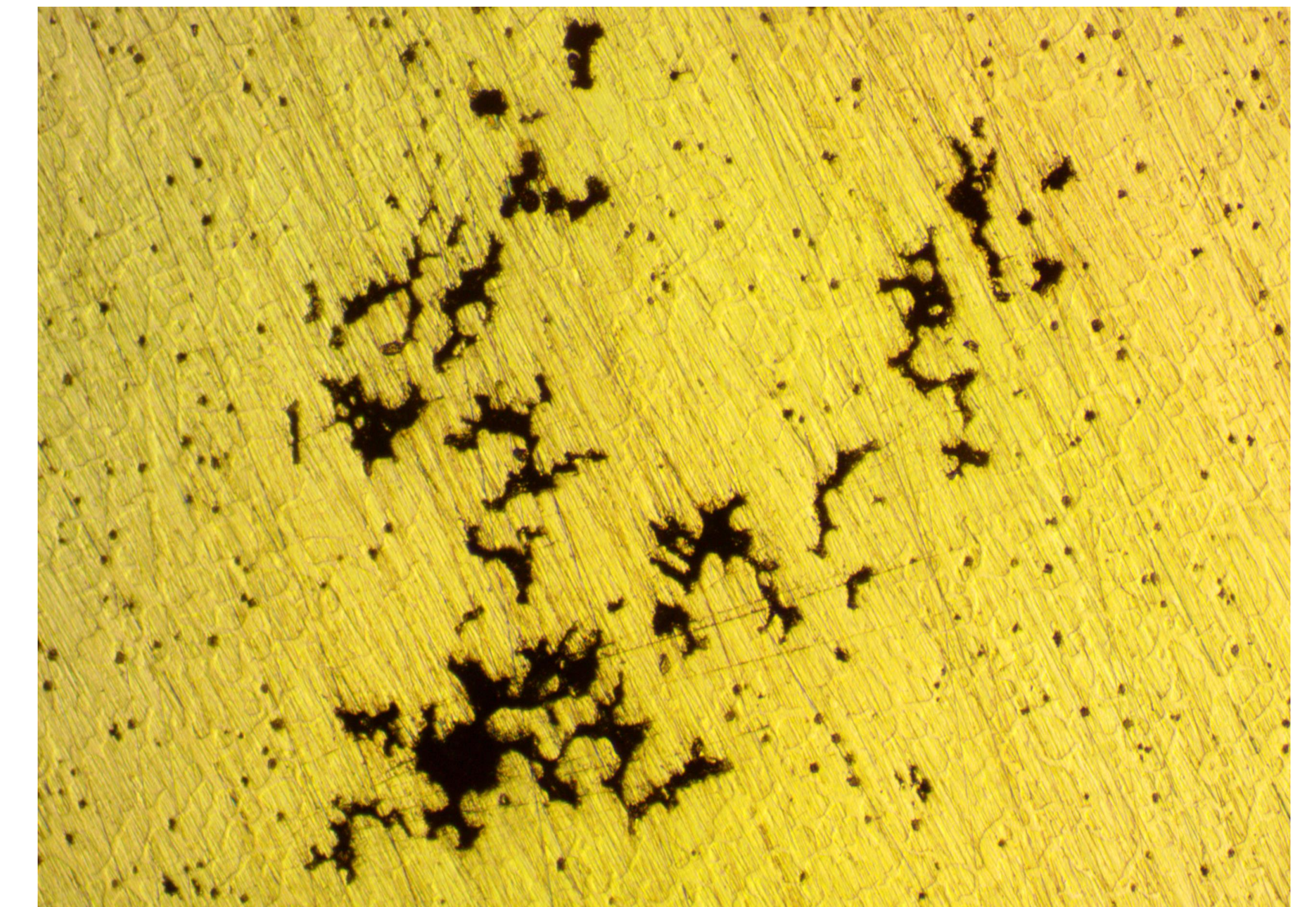
Final Design

3D printed ABS pattern components were epoxied onto a machined 6601-T6 aluminum matchplate to make the pattern board. This was installed into the Sinto FDNX to produce the olivine sand mold. Before pouring the DI, jackets were added to help prevent floatation and breakout. A pouring cup was added as well to provide a larger pouring target; then molten iron was poured into the mold to produce the casting.



The final casting design has several parts to produce optimal castings. These include a well at the bottom of the sprue to contain the initial splash-down of the molten metal, a filter plus trap to prevent any slag/dross/non-metallics from entering the casting, a stepped runner to keep the flow rate consistent, another well at the end of the runner so the initial flow of metal does not splash back, and risers to attempt to prevent shrinkage defects.

Testing and Results



The photomicrograph above shows the microstructure of the ductile iron that we cast. There are graphite nodules present in the image, which proves that we successfully cast ductile iron. Also, micro-shrinkage is depicted in the image above. This is a defect caused by the metal shrinking as it cools and solidifies. There are two factors that we believe may have contributed to the shrinkage defects. The main factor is undersized risers. The risers are significantly undersized, so they were not able to sufficiently feed the test bars as they solidified. The other factor is that we lost a lot of the carbon content due to equipment issues during the operations, so our graphite nodules were very small, which may have contributed to excess shrinkage.

The image shown below is one of our casting. The mold was completely filled and there are no large defects seen in the castings.

