French Mountain Studios – December 1, 2023

Bio-fuel Foundry Report

Project overview:

Bio-fuel foundry

French Mountain Studios has partnered with faculty, engineers, fabricators, and artists from across the world to devise a modular, scalable, and replicable foundry system that is now virtually independent from legacy fossil fuels such as foundry or metallurgical coke. The intent has always been to create technology that can operate on renewable fuel that is less carbon-intensive and cleaner regarding emissions. Our approach to melting iron without coke has been focused around the communal and performative aspects of iron casting, therefore designing and building a melter that operates in a similar fashion to the the classical cupola or cupolette. It was imperative that we design and build "off the shelf" as much as possible to allow for a scalable and replicable system that most artists or institutions would have access to.

Our most recent prototype has culminated in an efficient and clean-burning foundry furnace capable of producing high quality metal at speeds comparable to coke-fired furnaces. The burners that we have commissioned for this project are proficient at atomizing multiple fuels for use in the furnace, and the burners themselves are modular and capable of powering the cupolette foundry, a crucible melter, burnout kilns, forges, and even shop heaters. This flexibility will allow for not only a new cleaner burning iron foundry furnace, but the ability to melt other alloys in multiple ways, as well as provide heat for blacksmithing or other related activities.

We have now determined that this technology is at a point where it can be presented to our communities as a functioning and viable solution for artists, industry, academic institutions, and cultural entities that are looking for a more modern and environmentally friendly process for melting alloy.

The following findings are not necessarily cumulative of the project, but direct results from our latest prototyping and testing for our specific iron cupolette.

Structural endurance test 12/2023

Overview

The fifth iteration of the bio-fuel cupolette performed as expected with good efficiency and an adequate heating/melting or charging/tapping cycle. This phase of the research was specifically to test the structural abilities of the refractory grate system under high temperature and operating conditions. Over the course of 90 minutes of charging, melting, tapping, and pouring of molten grey iron, the furnace effectively produced roughly 240-250 lbs of hot grey iron. The iron was poured into existing sand molds, and upon final inspection the flow and detail of the material in the molds was sufficient and comparable to that of classical coke-fired foundry processes. In addition, the new simplified grate system with increased air-cooling capacity worked quite well, effectively discharging excess heat in the stack to ambient air, eliminating the need for a liquid cooling system. upon inspection, it appears the grates are structurally sound, the refractory spheres held up quite well for the campaign, and will be able to be re-used in additional melts/campaigns

Burners

For this particular test, we decided to put the reconfigured pressure washer pump burner system through it's paces. The less-complex but reliable and effective compressed air burners have produced similar results in our foundry previously and are considered the primary solution for those outfits with appropriate compressor capacity. If you do not have access to a two-stage compressor, please contact us about the pressure washer pump burner solution.

The PWP burner had minor leaking, but performed well otherwise. The premise behind this technology is that the foundry can operate without a large-capacity compressor and operate off of 110V electrical power. The burner has digital controls allowing to fine-tune operation regarding pressure/output and pre-heating. The burner will pre-heat oil to a temperature (110F) where it atomizes easily, creating an efficient delivery of fuel. Operating from a cold start with the 4 GPH nozzle proved slightly inefficient and the furnace struggled to start without the necessary heat in the lining to properly ignite all of the fuel. We reverted to a lower (2.5) GPH nozzle to reach proper stable ignition temperatures early on, and once the furnace showed visible signs of heat (dull orange color) in the well and lining, we exchanged the nozzle back to 4 GPH for the duration of the campaign. Exact oil totals were not documented, leaving us with a rough estimate of about 13 gallons of waste vegetable oil consumed over approximately 140-160 minutes of operation, for roughly 4.5-5 gallons of fuel consumed per hour. The system will allow for a bio diesel (or traditional hydrocarbon diesel) to be used as a burn-in fuel for more efficient preheating, but it isn't necessary.

Bottom and well

The well of the bio-fuel furnace is another major departure from the classical coke fired furnace. In the coke fired cupola, bed coke acts as the support structure for the stack of coke and iron, would retain heat in the well, and took up considerable space in the well, reducing the volume of molten iron the well can hold. In addition, coke fired furnaces would always need to have it's "bottom" dropped to relieve the stack of material that would ultimately fuse when cooled and freeze up the furnace. Our system of ceramic shell coated refractory board over sand eliminates the loss of volume from the coke, and allows for a bed to be used for multiple campaigns. This enables a smaller combustion stack and well to produce a larger quantity of molten iron.

Grates and Wind Belt

This was the 5th iteration of the furnace overall, and the 4th different style of grate used to support the upper stack of refractory spheres and charge metal. Prototyping led us to employ a dual-grate system, with tapered openings allowing for a a concentrated blast of heat to permeate the stack and preheat/melt iron while simultaneously employing three 1" rectilinear steel conduits for air-cooling per grate. The cooling process was powered by a lower CFM squirrel cage blower through a custom split wind-belt design, essentially shifting the traditional wind belt system from forced air combustion to forced air cooling.

These grates were layered on top of the well section of the furnace, gasketed in place with refractory bott mix, and offset roughly 90 degrees from each other. This criss-cross design allows for a more even flow of heat up, metal down, and allows the 6 cooling ports per side to fit within the split wind belt. Our chosen refractory at this point has been the Plicast HyMOR 98V KK high alumina low moisture castable. Proper firing sequences for the refractory are imperative to

(grates shown upside down to reference taper)

durability and sustained high temperatures in a high iron and oxygen environment.

Coupled with the new grates were 3” Plicast spheres that support the charge metal and allow for super-heated gas to permeate the stack and melt metal.

Fuel

Our fuel has been exclusively waste vegetable oil from food service institutions or private industry. While the versatility of the burners will allow for the delivery and combustion of various fuels such as diesel and motor oil, our primary objective is to operate on biofuel or a renewable plant-based oil. Waste fryer oil or reclaimed vegetable oil has no known carcinogens and will clean up with soap and water.

Prep, filtering, storage, and delivery of the oil to the foundry has been one of the major hurdles for this project, even though it appears fairly innocuous and straight forward on the surface. Ultimately we have determined that any extraneous moisture in our fuel can derail a melt/firing and the utmost care to remove moisture is imperative. Utilizing a conical tank, initial filtering and prep allows for the removal of coarse particulate and moisture. We filter the waste oil initially with a coarse strainer and then a fine mesh stainless strainer into the conical from the bucket or jug where initially stored. after coarse particulates are removed, the oil will sit and separate for a few days minimum, allowing the moisture to sink. Water and additional sludge/particulate is then decanted off into a waste bucket until the oil runs clear, where it is then further filtered with a fine mesh funnel back into clean containers for storage. Designing and devising the proper filtering and storage solutions for the biofuel foundry is essential, and will reduce potential spills and inefficiencies in the process.

Design/Build

French Mountain Studios and our partners are committed to promotion and advancement of this system and it's processes for the greater cast iron art community. We believe that the foundation laid over the last three years of research will provide solid footing for additional research and exploration into ways to improve metal casting and sustainable foundry practices. While we have decided to open-source much of our findings to the public, we are planning on taking select design/build projects and consulting work for those who are interested.

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