

### Abstract

Students were challenged to create an authentic African Spear Point by exploiting the steel casting manufacturing process. This challenge is presented by the Steel Founders' Society of America (SFSA) for their annual Cast in Steel competition. Simulations of the liquid metal flow and finite element analysis on the spear point were conducted to ensure the design was valid. The students cast the final spear point design with a high-carbon steel recipe at the Trine University Foundry. Then, the spear point was cleaned, heat treated, polished, and sharpened. The final spear point is 12 in. long, 3.25 in. at its widest point, and weighs 1.6 lbs. With the final product, testing was conducted to ensure the strength and durability of the material would be able to withstand the final performance evaluation at the competition. The team traveled to the 2023 Cast in Steel competition in Cleveland, OH, to compete against other schools in a series of tests to prove the worthiness of their spear.

### Customer Needs and Requirements

Need	Requirement	Unit	Value
1	Spear Point Weight	pounds	< 2.2
2	Spear Point Length	inches	< 20
3	Rockwell C Hardness	HRC	40 – 50
4	Ultimate Tensile Strength	ksi	188 – 243
5	Authentic African Spear Point	Pass/Fail	Contains all Parts of a Spear (Figure Below)
6	Casting Material	Pass/Fail	Steel Alloy
7	Industrial Partner	Pass/Fail	Steel Partner Foundry



### Material Selection



Molybdenum Ferrochrome Ferromanganese Ferrosilicon Nickel

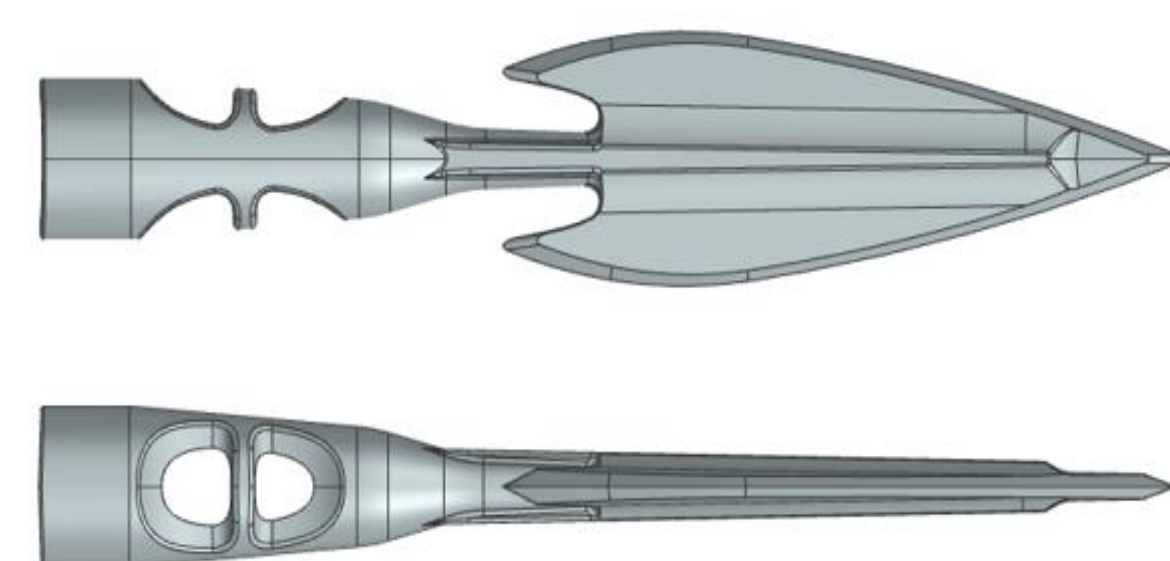
Because of the effects of the additives on the steel characteristics, this concentration of alloying elements were added.

For the competition, high impact, strength, and toughness properties are important. The alloy was developed with this in mind. Molybdenum, chrome, and carbon improve strength and wear resistance. Nickel preserves toughness while strength increases. The rest improve the purity of the metal and toughness.

	Additives	Si	Al	Mn	Ni	C	Mo	Cr
Goal	wt%	0.25	0.02	0.85	0.2	0.8	0.2	0.85
Actual	wt%	0.15	0.06	0.379	0.185	0.6	0.188	0.92

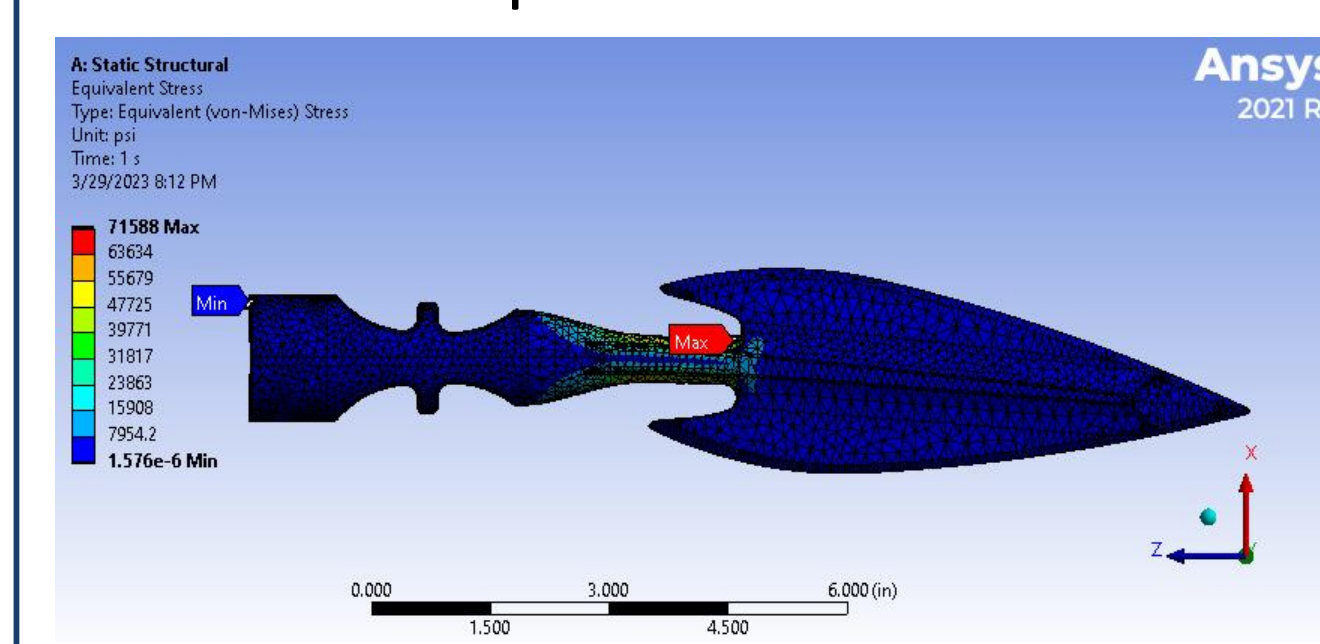
### Design Solution

- Final design verified and compared to previous iterations

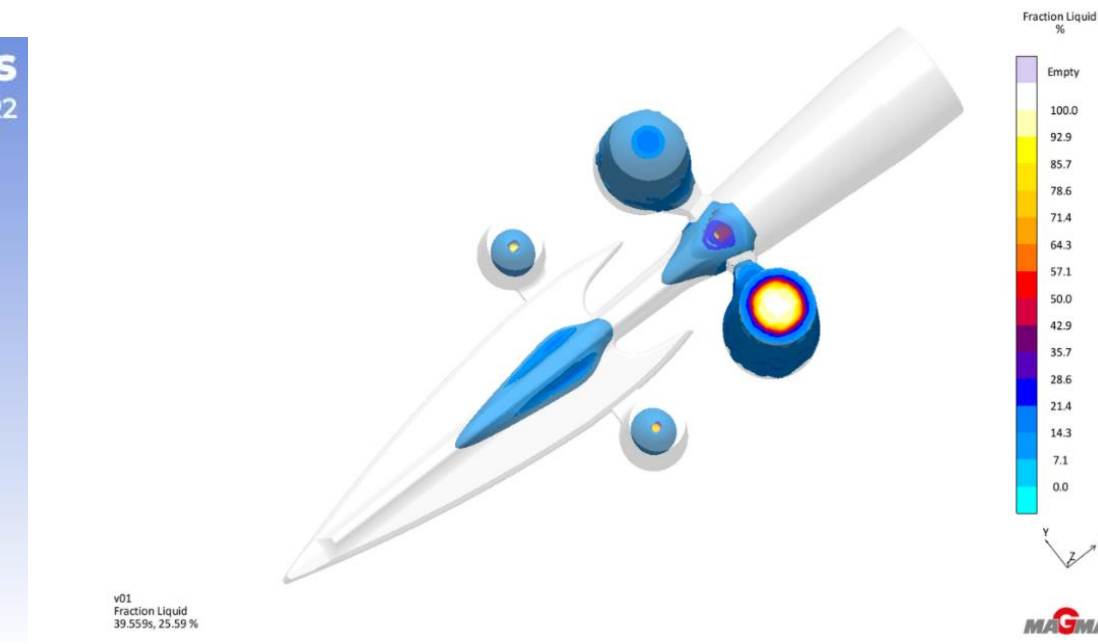


Green sand molding used for iterations before final pour in no-bake molds

CAD drawing of final design



ANSYS simulation for final design



MAGMA simulation for final design

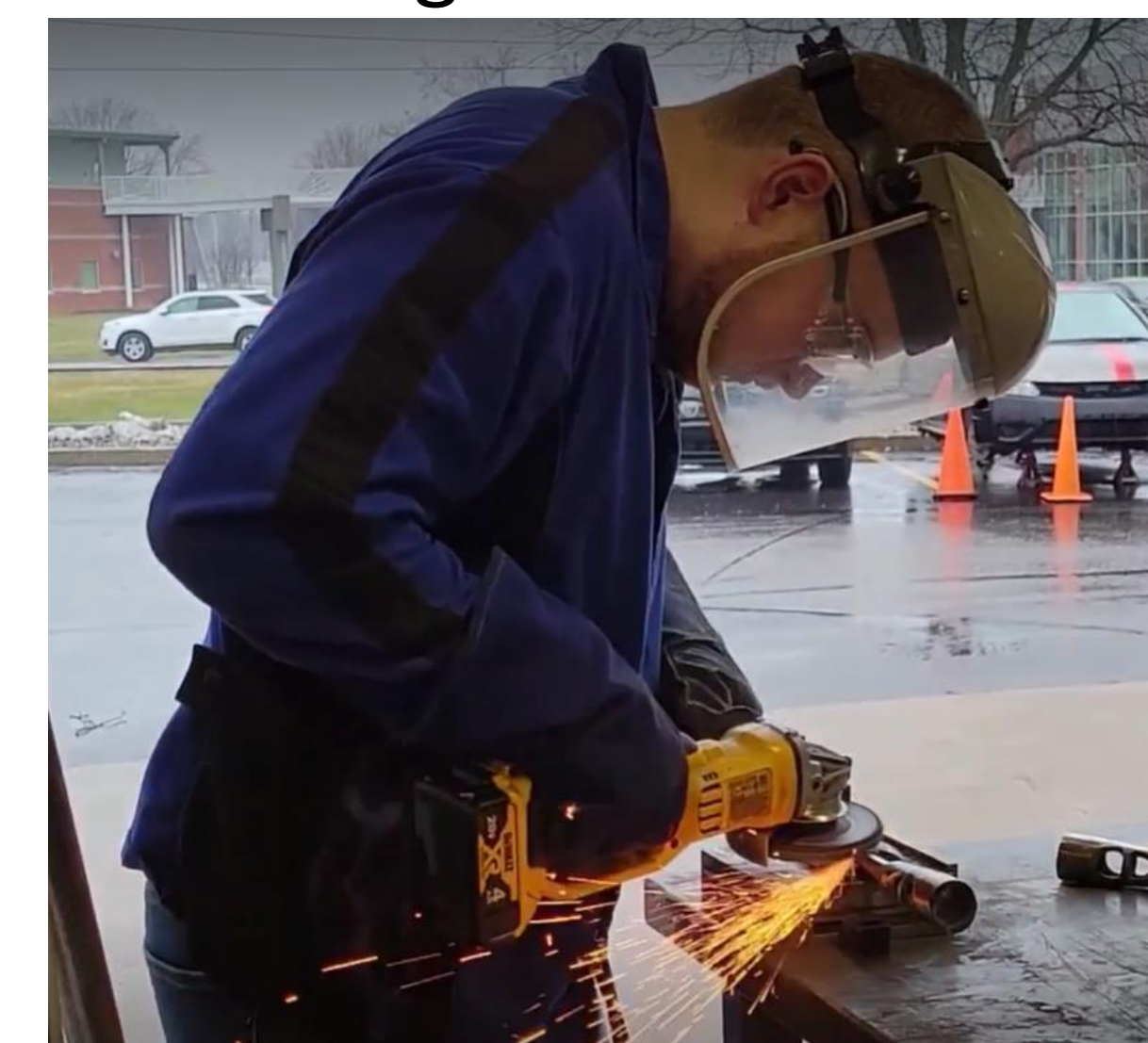
### Manufacturing

#### Pouring



- A set chemistry was melted in an induction furnace
- Molds were poured at a desired temperature for ideal filling

#### Processing



- Rough surface is ground smooth
- Blade edge is formed and sharpened on belt grinder

#### Heat Treatment



- Quenched to increase hardness
- Double-tempered to improve toughness

#### Finished Product

- Spear is polished with a buffing compound
- Polished and sharpened spear is attached to handle with epoxy



### Testing and Validation

#### Test 1 – Strength and Durability:

- Spear was forcefully hit against steel conduit three times
- If no deformation on any part of spear, test was successful



#### Test 2 – Slicing:

- Spear was swung into pipe insulation
- If pipe insulation was fully cut, test was successful



#### Test 3 – Hardness:

- Rockwell B and C for final heat-treated specimen
- If preset number was achieved, test was successful



### Acknowledgments



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