2020 SFSA Bowie Knife Competition Technical Report

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Penn State Behrend Foundry Industry Partners:

Urick Ductile Solutions, Erie, PA
PRL Industries, Inc., Cornwall, PA

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Although our team has a combination of Engineering Design, Material Science, and Knifemaking experience, it pales in comparison to that of our industry partners. To that, we would like to extend our most sincere thanks to everyone at Regal Cast, Hoosier Pattern, and Urick Ductile Solutions, without your help we would not have been able to pull this one off!

1. Introduction/ Background and Rationale Behind the Design

The first Bowie knife was claimed to be made in 1838 by Resin P. Bowie, brother of the famous James Bowie. He designed it as a hunting knife and gave it to his brother James to use for protection [2]. The first bowie knife was created in the 1820s by blacksmith Jesse Clifft who forged the knife based on Resin Bowie's design. The original Bowie knife design was similar to a butcher's knife in profile with a straight back and no clip point or hand guard. These knives varied in length from 8 ½ to 12 ½ inches and were only sharpened on the true edge [4]. Wooden handles were attached to the knives with silver pins and washers. When these knives were first created, they were considered the ultimate utility knives, being able to be used for almost everything, from the butchery of animals to clearing paths [1]. The Bowie knife came to fame after the Sandbar Fight on September 19, 1827 near Natchez, on the Mississippi state side of the river. On that day, Samuel Levi Wells and Dr. Thomas Maddox engaged in a duel with little effect, however members of the Maddox group fired at Well's followers, who included James Bowie. Bowie, who was shot through the lung by the Maddox group, lay on the ground incapacitated, began to be stabbed with sword canes. In one last ditch effort to save his life, Bowie raised himself, grabbed his knife, and stabbed, Maddox group member, Norris Wright in the heart, killing him instantly [4]. The Sandbar fight is what began the legacy of the Bowie knife and its widespread use. Throughout the years, the Bowie knife has become less of a combat knife with the introduction of more reliable pistols, but to this day they continue to be used as hunting and utility knives [1]. Many Bowie knives made today have more decorative features compared to their forged counterparts in the early 1800s. Even though the design and use of the Bowie knife has changed throughout time, the beginnings of the Bowie knife will never be forgotten. "In the history of American arms," wrote historian Harold L. Peterson (1958), "three weapons stand out above all the rest: the Kentucky rifle, the Colt's revolver, and the Bowie knife." Each became a part of the "great American Legend"[4].

Our knife can be described as a drop point bowie with a double guard. The overall shape of the knife was selected to easily be identified as a bowie knife, as well as to comply with competition requirements for blade length, hand guard, and integral pommel. The knife balance point occurs just in front of the hand guard, helping for chopping yet not being so front heavy as to make recovery from a swing impossible or tiring.

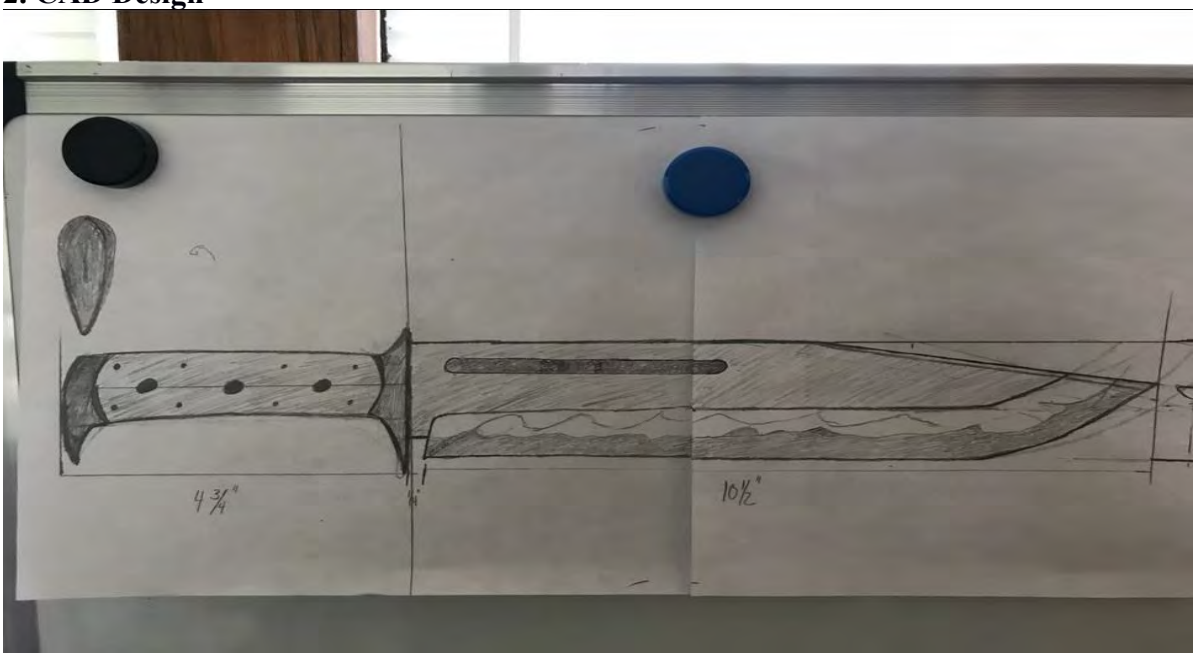
The primary knife model was initially hand drawn on paper and then imported into CAD. After several iterations a final design model was mutually agreed upon and selected to proceed by all group members. To ensure that the knife proportions were adequate, the CAD model was 3D printed and adjusted, iteratively, until a final model was selected. This CAD model was then sent to Regal Cast where the final mold design and fluid simulations were conducted by Laura Karduck. Those mold files were then sent to Hoosier Pattern to be 3D binder jet sand printed on their X1 3D binder jet sand printer. These molds were then sent back to PRL Regal Cast where the pour was conducted. The alloy that was used for the knife was USAF-9628. It was selected because of its casting ability, good balance of strength/ hardness/ impact toughness, and the team's familiarity

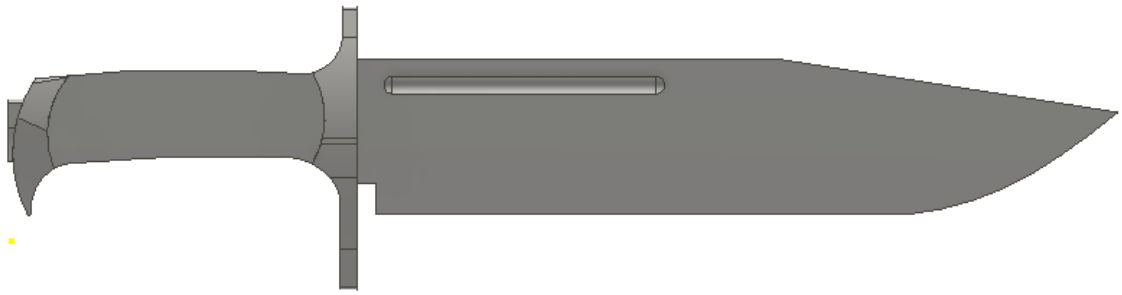
with the alloy. It was also chosen due to its similarity with alloys that our foundry partner casts on a daily basis, to help achieve the best outcome possible. Once the castings were shaken out, they were sent via mail to our group where all machining, grinding, heat treating, and polishing would be hand done by our team members at their homes.

The initial cleanup of the casting was completed using a 2 x 72 inch 36 grit sanding belt to quickly remove the flashing and rough surfaces. The casting was then machined using a vertical milling machine to ensure the knife surfaces were flat and parallel. The primary bevel was hand ground again using a 2 x 72 inch belt grinder starting with 36 grit abrasive belts and continued to be ground until a 220 grit belt was reached. Once the profile and most of the bulk stock removal was completed, the knife was polished using a combination of 2 x 72 inch Scotch-Brite belts, a Muslin buffing wheel, and a Denim buffing wheel to achieve its final finish. Holes for handle pins were drilled pre-heat treatment using carbide endmills to ensure an accurate hole size. The edge of the knife was left intentionally thick before heat treat to reduce the risk for warping in the quench and was coated in anti-scale compound to avoid oxidization. To harden the blade, the knife was placed in an electric heat-treating furnace set to 2,125 °F and quenched directly into room temperature water, resulting in a hardness of approximately 55-60 HRC. Following this, the knife was tempered at 400 °F for an hour.

After heat treatment, the knife was sharpened on a belt grinder and had handle scales comprised of carbon fiber and iron wood with a pattern welded copper and nickel “mokume gane” spacer placed between them. Once the handle scales were sized, two 3/16” copper pins and one 1/4” mosaic pin were set in place along with the handle scales with two-part epoxy and left to dry. The handle was then sanded to fit comfortably in the hand and rubbed with Tung oil to reveal the grain in the wood. A Kydex sheath was then formed around the finished bowie knife and shipped to SFSA for judging.

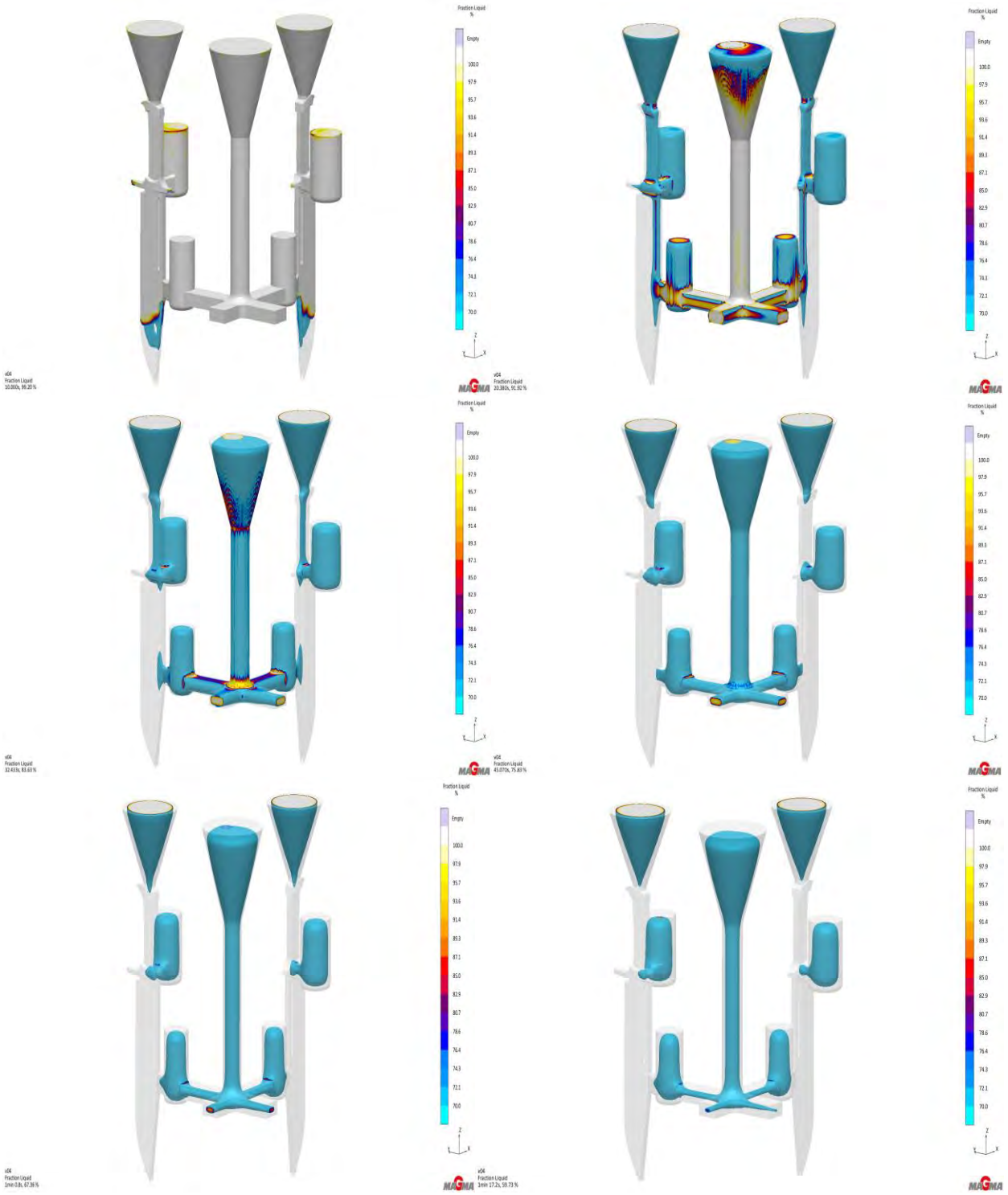
2. CAD Design



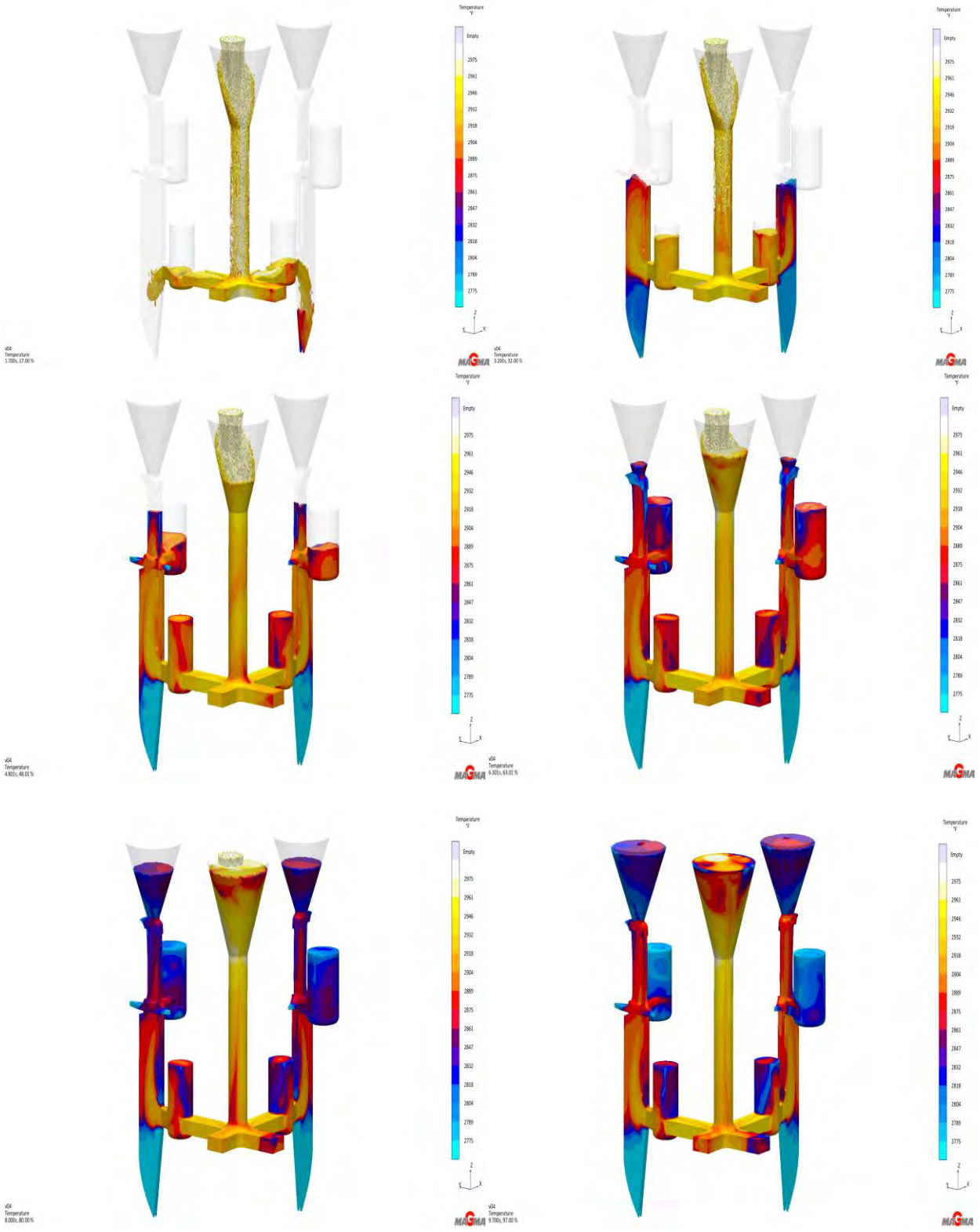


3. Simulation Modeling for Process and Performance

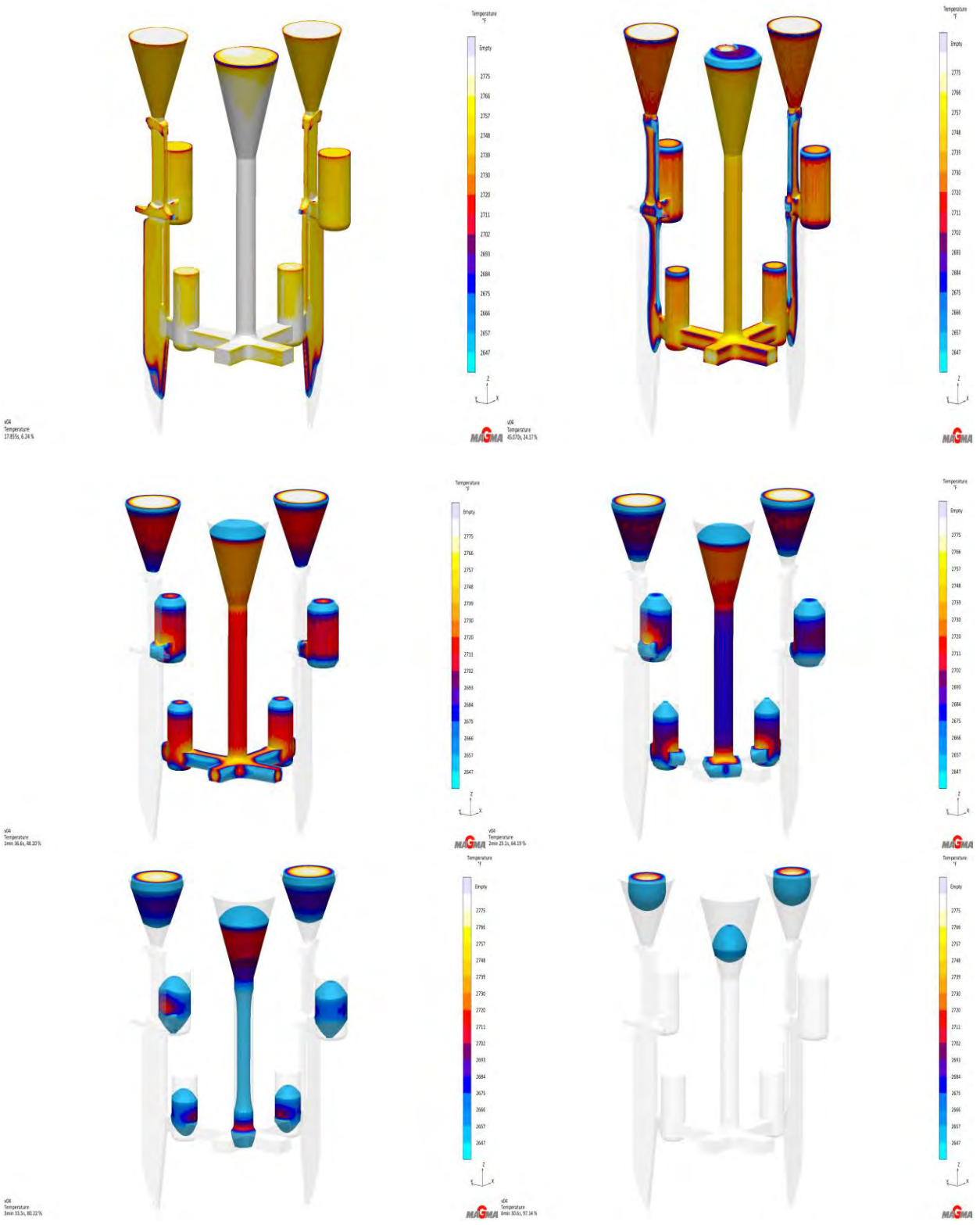
Fraction Liquid



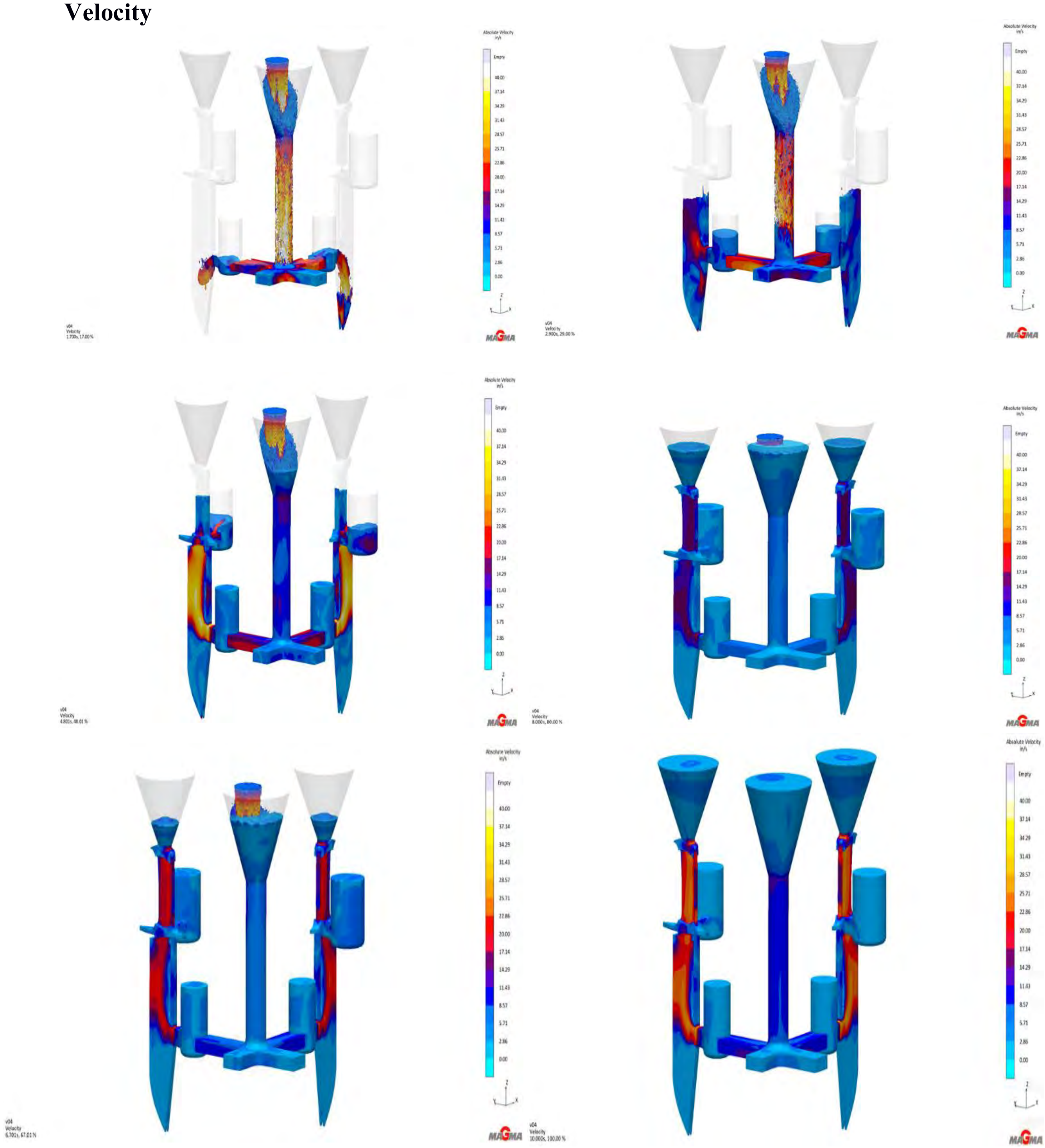
Temperature Initial Flow



Temperature Solidification

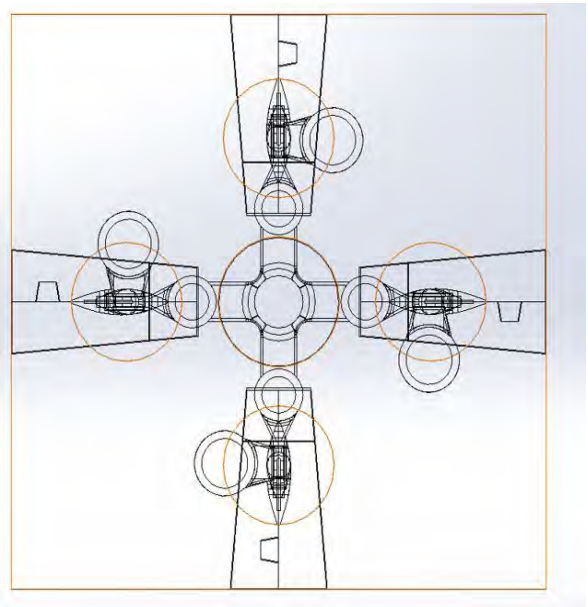


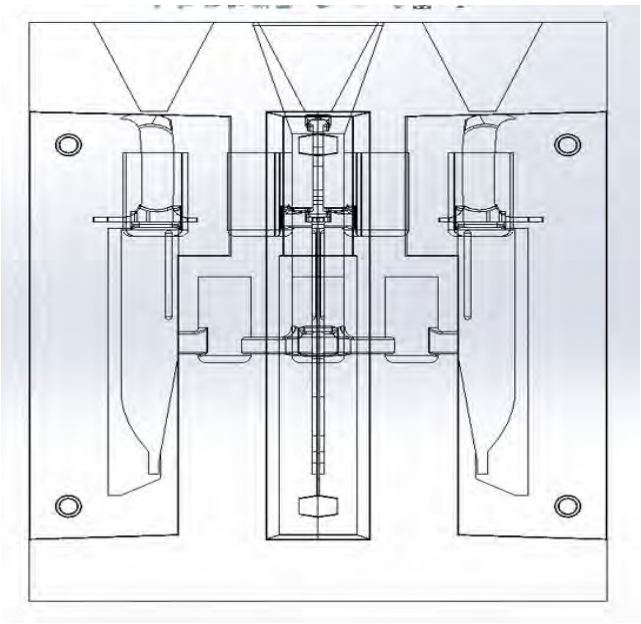
Velocity



Absolute Velocity
in/s
Empty
40.00
37.14
34.29
31.43
28.57
25.71
22.86
20.00
17.14
14.29
11.43
8.57
5.71
2.86
0.00
MAGMA
v04
Velocity
1.700s, 17.00 %
v04
Velocity
2.900s, 29.00 %
v04
Velocity
4.801s, 48.01 %
v04
Velocity
8.000s, 80.00 %
v04
Velocity
6.701s, 67.01 %
v04
Velocity
10.000s, 100.00 %

4. 3D Sand Printed Molds





5. Steel Alloy and Chemistry

The guidance for alloy chemistry, melting, and heat treatment was adopted from the AF 9628 patent [3].

The general alloy chemistry reported in the AF 9628 patent is as follows [3]:

Alloy Steel Composition Content by Weight (%)

Element	Approximate Percentage by Weight (%)
Carbon (C)	0.24 to 0.32
Chromium (Cr)	2.00 to 3.00
Molybdenum (Mo)	0.50 to 1.50

Alloy Steel Composition Content by Weight (%)

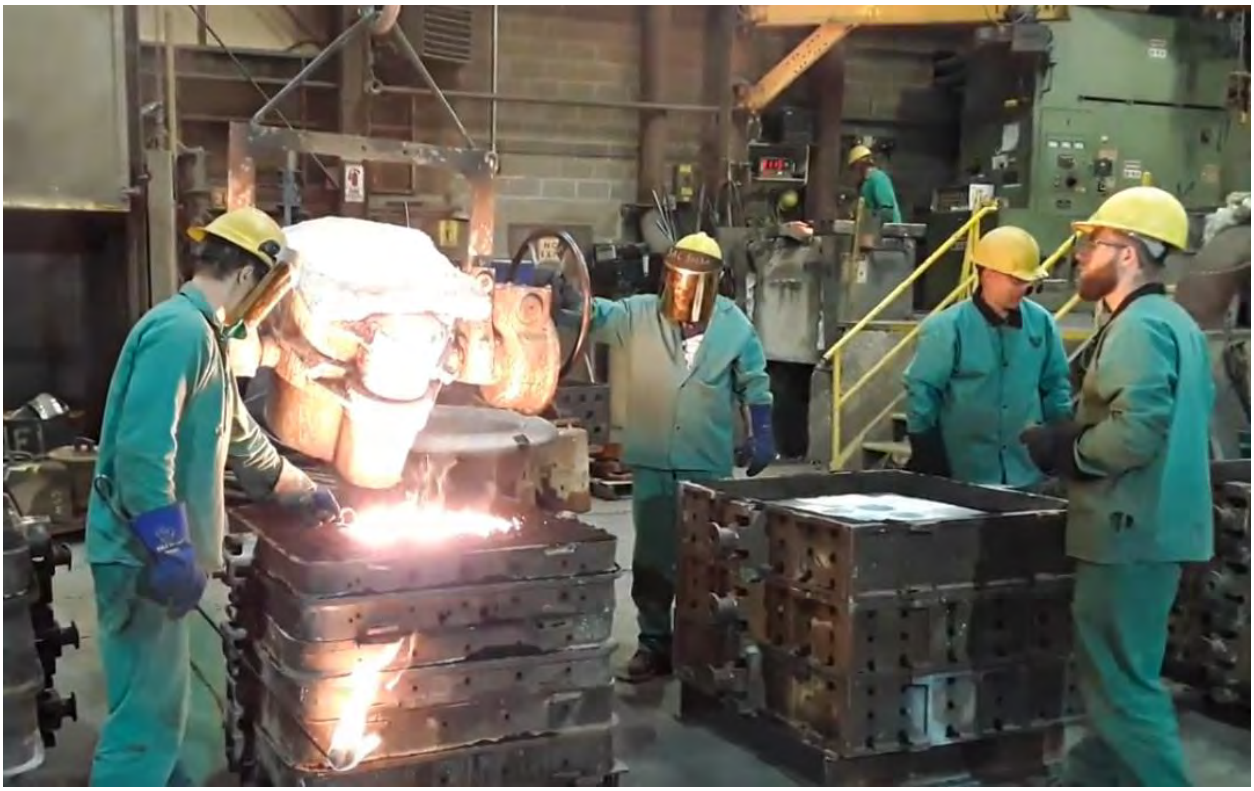
Element	Approximate Percentage by Weight (%)
Vanadium (V)	0.05 to 0.35
Manganese (Mn)	1.00 or less
Nickel (Ni)	3.00 or less
Silicon (Si)	1.25 or less
Copper (Cu)	0.15 or less
Phosphorous (P)	0.015 maximum
Sulfur (S)	0.02 maximum
Calcium (Ca)	0.02 maximum
Nitrogen (N)	0.15 maximum
Aluminum (Al)	0.025 maximum
Iron (Fe)	Balance

The AF9628 steel for this project was melted by PRL Regalcast in a coreless induction furnace, using 450 lbs. of revert (N9740D) & 350 lbs. of 1010 punchings (virgin material). The steel was tapped from the furnace at 3113°F and poured into the sand molds at 3000°F. The deoxidation procedure consisted of a ladle treatment of 2 oz. Fe Titanium and 7 oz. Aluminum.

The final chemistry for the alloy poured was reported as follows:

C	0.2652	Nb	0.0079
Mn	0.671	V	0.0395
Si	0.970	Al	0.0535
P	0.0093	Ti	0.0103
S	0.0129	W	0.0000
Cr	2.460	Sn	0.0073
Ni	0.962	Mg	0.0000
Mo	0.894	Zn	0.0000
Cu	0.0692	N	0.0198
Co	0.0082		

6. Melting, Pouring, and Shake Out



7. Heat Treatment

8. Images of the Production Process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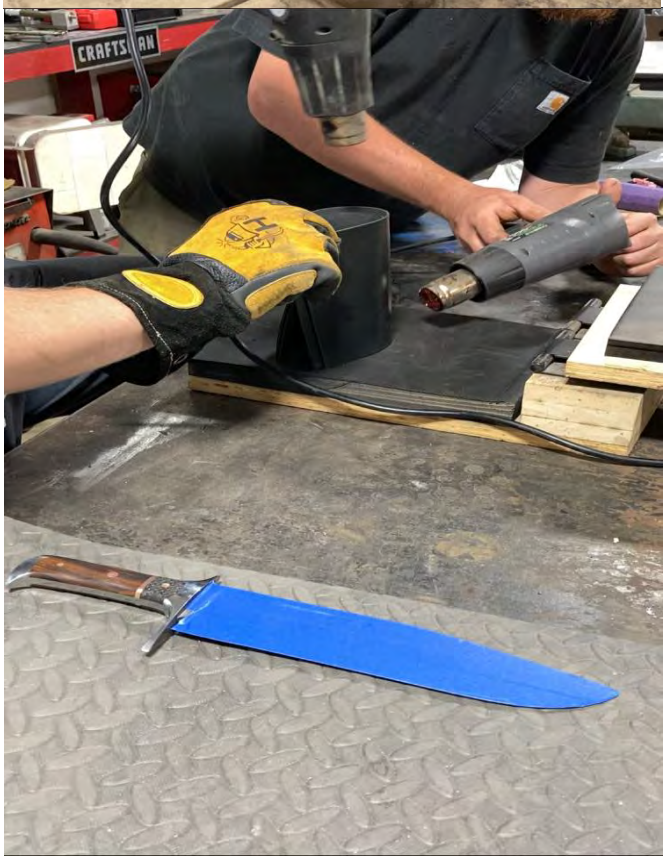
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Works Cited

[1]Andrews, Evan. “9 Blades That Forged History.” History.com, A&E Television Networks, 23 Apr. 2018, www.history.com/news/knives-that-changed-history.

[2]Bryant, John. “A Knife Like Bowie's.” A Knife Like Bowies, Mar. 2000, www.sonsofdewittcolony.org/adp/history/bios/bowie/knife_like_bowies.html.

[3] R. A. Abrahams, “Low alloy high performance steel,” U.S. Patent No. 20,160,369,362, 2016.

[4]Williamson, William R. “BOWIE KNIFE.” The Handbook of Texas Online| Texas State Historical Association (TSHA), 12 June 2010, tshaonline.org/handbook/online/articles/lnb01.