Steel Bowie Knife

Cast in Steel 2020

Submitted to

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This paper will discuss the design and process used for the making of a steel Bowie knife. This Bowie knife was made by Texas State University students and our sponsor, American Foundry Group Inc. We will discuss our reasoning behind our design, the materials selected, the modeling process used, limitations, and our results.

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Acknowledgments

We would like to express our most sincere appreciation to Abel Ardis of American Foundry Group Inc. for his support, guidance, and knowledge in aiding us with our project. His willingness to give his time and advice so generously has been very much appreciated and beneficial in manufacturing our Bowie knife. We also greatly appreciate his flexibility and patience to work with us during such a chaotic time.

We would also like to thank the Steel Founders Society of America for hosting this exciting opportunity to learn. This year's contest has definitely been unique in the challenges it proposed, and we appreciate the ability to finish this year's contest.

Integrally Cast Blade Guard and Tang

The modern Bowie knife has numerous uses in today's world and has advanced into one of the most common and versatile survival tools. It can be used for tasks such as cutting wood, skinning and cleaning game, and protection. However, today's iconic Bowie knife has a long history.

The Battle of the Alamo 1836, is a pivotal event in Texas history. Many Texas legends were a part of the heroic battle for Texas Independence, including Jim Bowie. Revered as a rough and gritty fighter, and known as for his level head and courage, he lost his life and gained his immortal fame as a hero at the Alamo. The death of every single defender of the Alamo gives rise to many images of bravery as Texans were fighting to the last, but no image is less poignant than Jim Bowie's mortal struggle with his faithful Bowie knife in hand.

Bowie grew up hunting, fishing, riding wild horses, and floating lumber. He was considered a rough outdoorsman and his reputation for brawling was the spark that started the famous legend of the Bowie knife. An eyewitness to the sandbar fight 1827, claimed to see Bowie, after being shot in the chest and thigh, thrust a "big butcher knife" into the heart of his opponent. After the legend spread, men asked blacksmiths to make a knife resembling Bowie's, and they grew widely popular since they were less expensive than a gun and could be used for many tasks.

As a tribute to our Texas heritage, we specifically wanted to recognize the Bowie knife based on Jim Bowie's original knife. Jim Bowie's knife was a distinctive weapon, branded with his initials JB on the guard. The knife had a unique "clip tip" at the end of the blade that aids in controlling the knife during thrusting, but is also useful while skinning, and cutting ropes. It also had a curved spine that helped aid Bowie in inflicting maximum damage to his opponents, but also still be able to be used for other tasks like hunting and fishing. We designed our blade, guard, and tang to resemble the shape and style of Bowie's Knife using Solidworks 3D design software (Figure 1).

During the design process, we created and incorporated the iconic Texas image from the Battle of Gonzales 1835, "Come and Take it" with the cannon and star, under the silhouette of the Alamo on the sides on the blade (Figure 2). This battle commemorates the first mighty engagement of the Texas Revolution. We also added a bobcat to represent Texas State. We added the JB and delicate patterns on the guard of the original Bowie Knife, however, they are very faint in our final casting. These engravings were incorporated in our model so it would not have to be machined in the final casting. The tang was designed to the original dimensions of Bowie's knife; however, we increased the width to better strengthen the handle and added an extension at the end. This extension is needed in the final steps of our process for attaching the pommel to the knife. We planned to thread the extension to allow for the pommel to screw to the tang and hold everything in place.

We choose between D2 and 440c for our alloy. While both alloys had desirable qualities, we choose D2 due to the higher edge retention and higher toughness. D2 steel is an air hardening, high-carbon, high-chromium tool steel. The chemistry of the D2 steel is attached below (Figure 3). This material was chosen because of the high hardness, 55 - 62 HRC, wear and abrasion resistant properties, however D2 is more brittle. This material was heat treatable, which was a characteristic we desired for our blade edge. This will increase the blades toughness. D2 is a common steel among knives because of the ability to retain an edge. Knowing that gave us more of an incentive to choose D2 over 440C. In conclusion, D2 steel has high abrasion resistance, which means that it would be tougher to sharpen but its edge would hold much longer.

With the help of our sponsor, Abel Ardis at American Foundry Group, we were able conduct a solidification analysis with MagmaSoft. In this stage of the competition, we were able to review a simulation of how the knife would act during the casting and solidification process. With this software, we were able to see areas of porosity, shrinkage, the mesh analysis, temperatures at all the nodes when it was solidifying and how different gating methods would help the casting solidify. During simulations we noticed porosity in the base of the tang. To eliminate this we redesigned our tang and tried several different gating methods (Figure 4) .We were able to select a gating system that provided better solidification and resulted in no porosity in the casting (Figure 5, 6).

Once our team was satisfied with the design and solidification analysis we proceeded with the next phase, casting. We choose to use an investment casting process because it would render the greatest level of detail in the engraved sections as well as a fully filled casting. We believed that this process would work best for the delicate nature of our casting. This process required a 3D wax printed model which was achieved by the help of a third party who supplied our sponsor with two 3D wax printed patterns (Figure 7). Our sponsor was able to connect our 3D wax pattern to the tree with our gating method and prepare the pattern for casting (Figure 8). Once our casting was poured, it was degated.

During the degating process, the high temperatures and brittle nature of D2 caused the tip of our blade to warp and chip (Figure 9.a, b, c). To overcome this, we choose to heat the blade and press it straight, however, the tip broke into multiple pieces (Figure 10). Fortunately, at this time in the competition we had the option to pour our second blade. Our sponsor prepared our second pattern with our same gating design and added ribs to the tip of the blade to help keep it straight. We choose to pour our knife out of 440c because we were familiar with its properties, and we believed we would have a better chance at degating this material (Figure 11). The change in material and the added ribs helped the knife degate easier however, the engravings were not as detailed. We received both our D2 knife with the broken parts and the 440c knife from our sponsor (Figure 12).

Upon inspection, we decided to weld the pieces of the D2 blade together (Figure 13). We preferred the qualities of the D2 steel and the surface finish of the engravings on the D2 steel blade. We used a TIG welding process with Er70s2 as the filler. This filler was chosen due to its ability to bond the steel and drive out impurities that may be present in the broken and thin cast steel. This filler also works very well with carbon steels that are not very clean, such as cast steels. After the pieces of the blade had been welded back together, we ground down the weld to make it flush with the surface and polished the surface of the blade to create the uniform finish (Figure 14).

At this point, the extension on the tang was threaded to a standard size 8 screw. (Figure 15). The blade, guard, and tang of the knife was then heat treated. The entire knife was heat treated starting with being fully hardened by bringing the steel up to 1000°C in an oxygen free steel pouch. Once the knife was uniformly heated it was allowed to soak for 30 minutes to allow the carbon to fully dissolve into solution. After the soak time, the knife was pulled from the furnace and quickly placed on a large billet of aluminum and sandwiched between another aluminum billet with a weight on top of it. The aluminum acted as a heat sink to quench the steel while also holding the blade straight while cooling. While the blade was cooling, we also blew compressed air across the blade to further accelerate and even out the rate of cooling across the blade. Once the knife has cooled enough to be handled it was quickly checked for hardness with a file. The file skated across the edge of the blade without digging in, indicating that the steel was hard. The knife was immediately placed into a waiting furnace heated to 230℃ and left to soak for an hour to temper back the hardness greatly increasing the steel's toughness at the expense of a small amount of hardness. The steel was allowed to cool to room temperature in still air. This tempering process was repeated 2 times in total. The blade was then sharpened by hand with a belt grinder and a whet stone. We aimed to achieve a tip angle of 25˚ which should help in hunting and skinning tasks and also allow for a sharper, longer lasting edge.

Handle and Pommel

The handle and pommel were modeled in Solidworks 3D design software (Figure 16). We wanted the handle to taper into the guard, yet still have enough strength when force is applied to the blade. To achieve this, we designed the handle to have a brass section at the front to add strength. Our team was able to 3D print the brass joint, handle, and pommel to test the fit and assembly of the parts before casting. The pommel was designed to wrap around the end of the wood handle and be secured to the tang by a female threaded counterbore screw. We also added a small Texas and "TXST" to represent our university.

Once the parts were printed and tested, we were able to 3D print small wax parts for investment casting (Figure 17). Our team printed the brass joint, pommel, and screw and prepared the wax patterns for investment casting. They were attached in a tree, coated in a fine slurry, poured with yellow brass, and left to cool (Figure 18). This material was selected because we were familiar with the casting qualities since we use it in the labs here at our University. Once the casting had cooled, we degated and cleaned the parts. The screw was threaded to fit the threads on the pommel, a standard size 8 (Figure 19).

In out final step of our Bowie knife process, assembled and shaped the handle. The wood section of the handle is made from oak. We cut a block roughly to shape and then drilled a hole down the center for the tang to slide through. Once assembled, the wood block was sanded and shaped to fit comfortably in the hand. During this step, the tang unfortunately broke (Figure 20). Our team again used creative problem solving to repair our Bowie knife by TIG welding the tang back to the guard (Figure 21). We were able to snugly fit the handle and pommel assembly together.

As a final touch, the wood section was stained with a red oak stain to darken and protect the wood. Our completed Bowie knife blade measures 9.2 inches and the knife measures slightly over 13.5 inches in total (Figure 22).

Limitations

Due to the unfortunate nature of this year's competition our team, like many others, faced challenges due to Covid-19. Thanks to the help of our sponsor, our team was fortunate enough to have enough progress on our knife that we were able to complete it. For our area, Covid-19 broke out and we were not allowed to work safely on campus when our sponsor was casting our first blade. This caused a major delay in completing our knife. During this chaotic time, we were able to regather, and come up with a solution as to how to finish our knife. Fortunately, our team gained access to the needed equipment that allowed us to finish. However, it must be noted that we were only able to complete our knife due to our creative thinking and a little luck. The extension that was given was also a needed asset to be able to complete our knife.

Conclusion

We believe that our Bowie knife will hold up in sharpness and durability. The hardness of the D2 steel will help hold the edge of the blade while the heat treatment will reinforce the toughness and durability of the knife. We also believe that the shape and style of our Bowie knife will promote speed and diverse usability, as a knife should. Due to the design, careful processes used, and extreme resourcefulness of our team, we believe that our knife will exceed our project requirements.

Photos

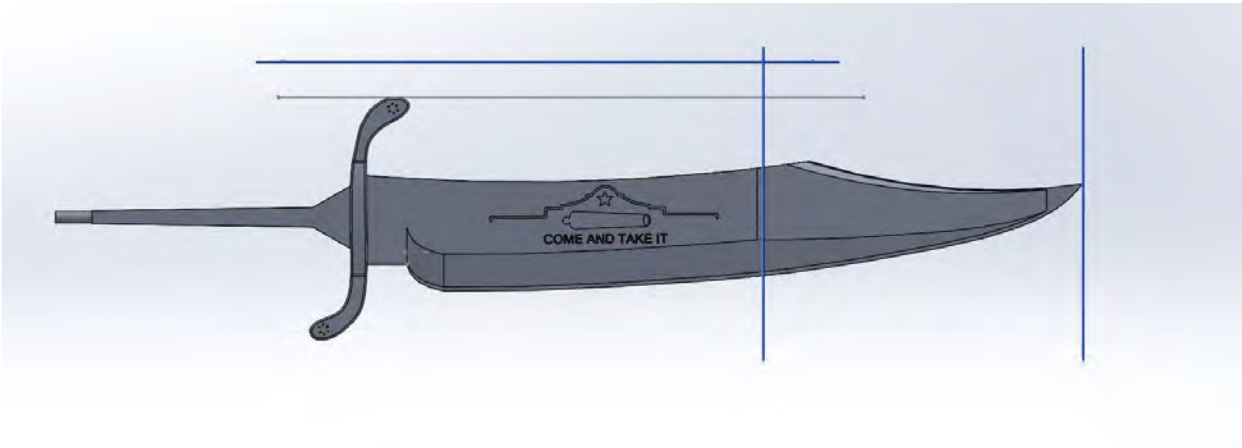

Figure 1. Original design of Bowie knife.

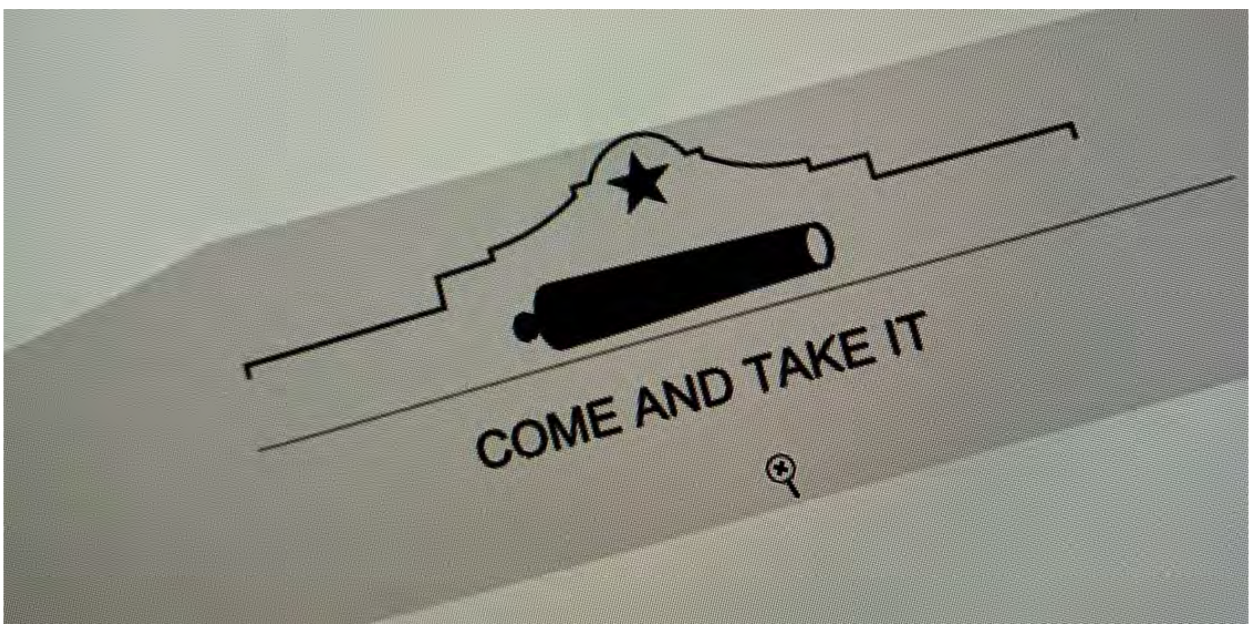

Figure 2. Engraving on sides of blade.

Chemical Analysis (%)												
Element	C	Mn	Si	Cr	Ni	Mo	P	S	V	Cu	W	AS
Spec. Min	1.40			11.00		0.70						
Spec. Max	1.60	1.00	1.50	13.00		1.20	0.03	0.03				
Actual	1.5	.75	1.05	11.94		.90	.02	0.010	.6			
Element	Fe	Cb/Nb	Co	Sn	Sb	Zn	Al	Pb	Ti	Mg	N	Zr
Spec. Min												
Spec. Max												
Actual			.6									

	MAX	ACT		MIN	MAX	ACT		MIN	MAX	ACT
C E:			Ferrite:				PREN:			

Figure 3. D2 Steel chemistry.

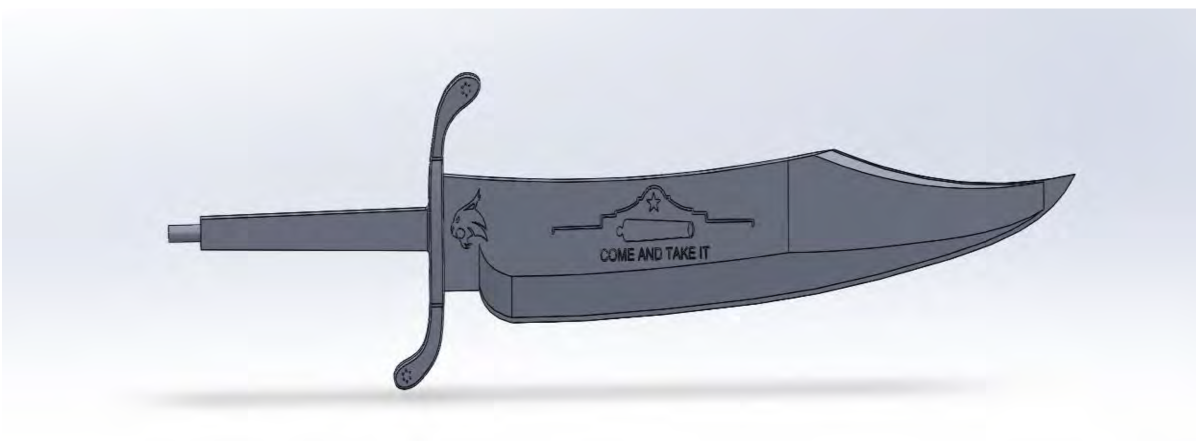

Figure 4. Final design of knife.

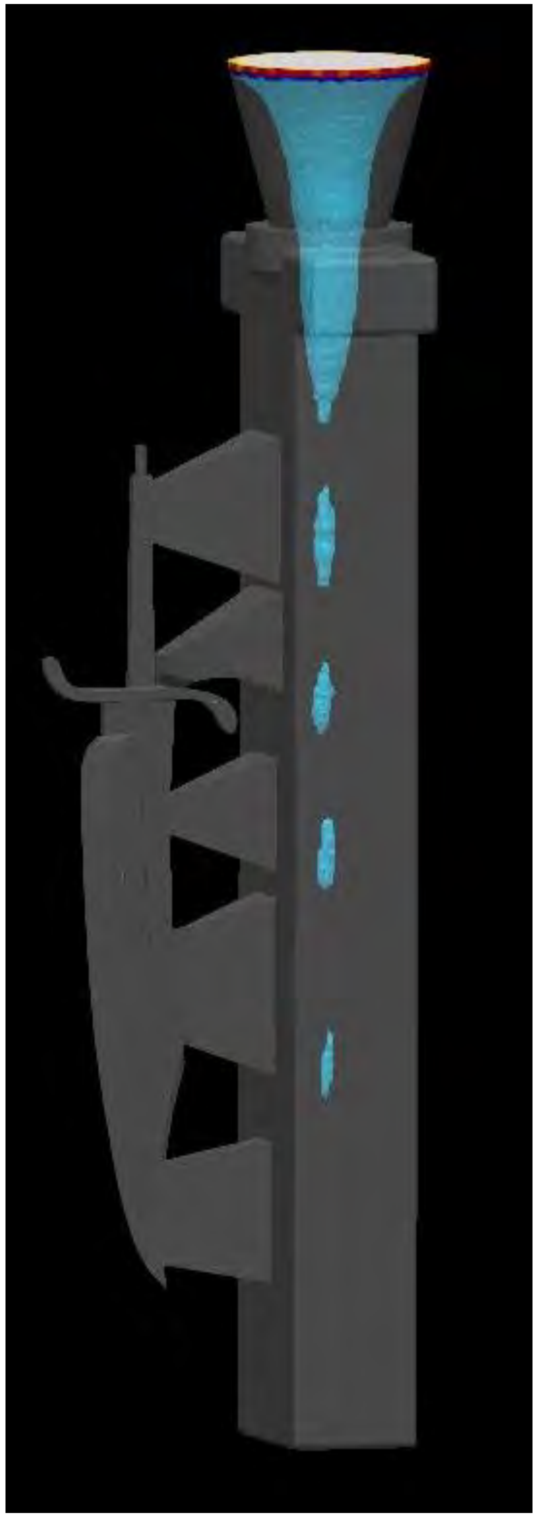

Figure 5. MagmaSoft simulation showing porosity results.

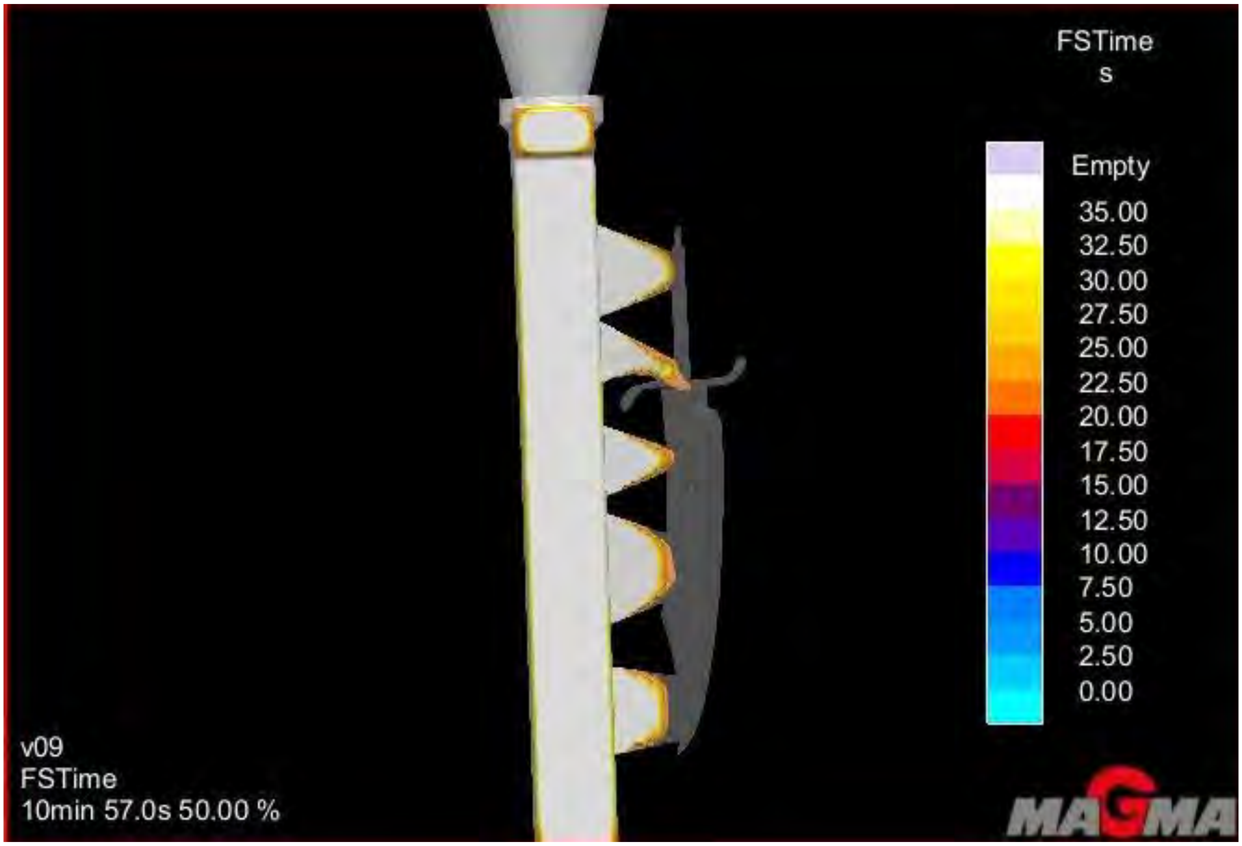

Figure 6. MagmaSoft simulation showing the critical points durring solidification.

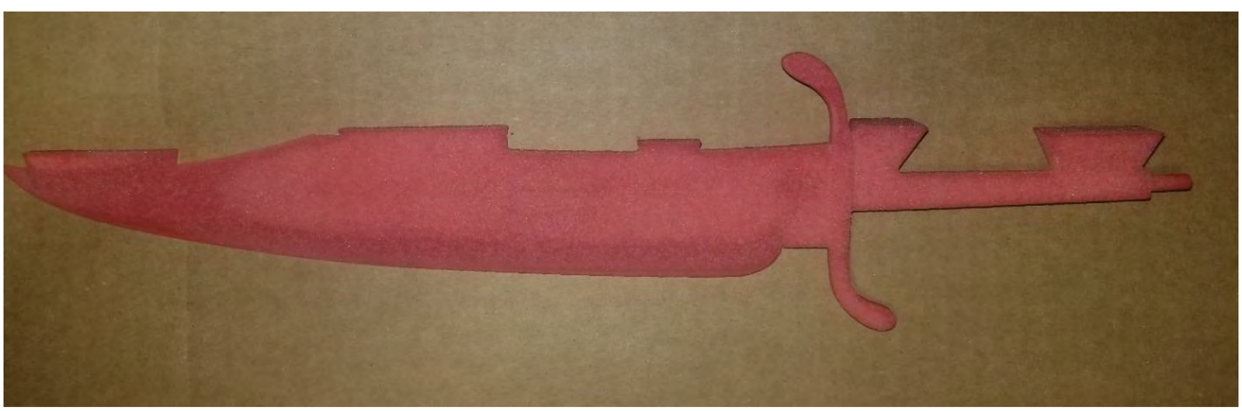

Figure 7. 3D was printed pattern.

Figure 8. Mold of Bowie knife prepard and ready for investment casting.

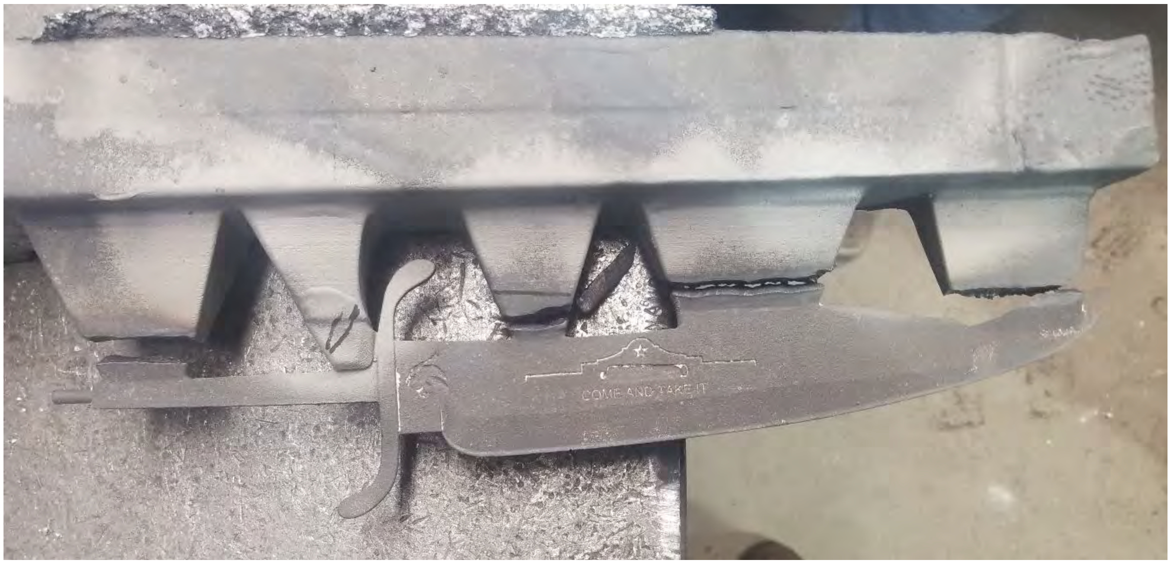

Figure 9.a. Chip in D2 steel Bowie knife durring degating process.

Figure 9.b. Chip in D2 Steel Bowie knife post degating process.

Figure 9.c. Warp in D2 Steel Bowie knife post degating process.

Figure 10. D2 Steel Bowie knife broken tip after straigthening.

Figure 11. 440c Bowie Knife particially demolded.

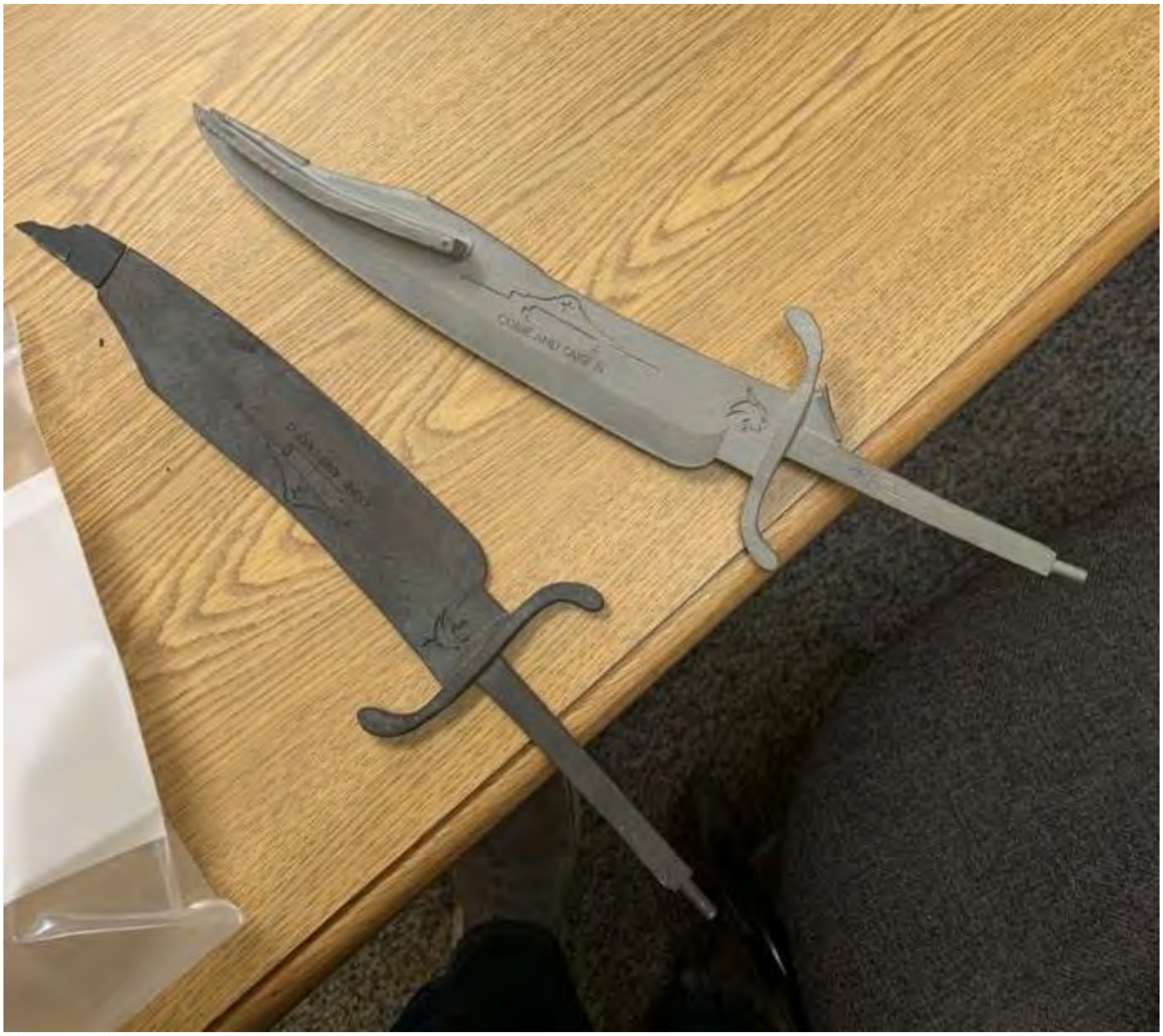

Figure 12. A side by side comparison of the two Bowie knives.

Figure 13. Tip of D2 steel knife TIG welded together.

Figure 14. Weld ground flush with surface of D2 steel Knife.

Figure 15. Threaded extension on pommel.

Figure 16. 3D modeled version of handle and pommel assembly.

Figure 17. 3D wax printed pommel, brass joint, and screw.

Figure 18. Casting of pommel, brass joint, and screw.

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Figure 19. Threading process of screw in pommel assembly.

Figure 20. Broken tang during assembly.

Figure 21. TIG repair of tang.

Figure 22. Final Bowie knife.