Cast in Steel 2020

Technical report "Bowie Knife"

University:

Instituto Tecnológico de Morelia

Commercial Foundry:

Fundidora Morelia S.A. de C.V.

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Bowie Knife Features

We do consider really important to know the historical background of these Bowie type knives and the reason why they are known by this name, so we could fulfill all the historical requirements that fully allow us to consider our knife as a Bowie Knife.

The Bowie Knife is a cold weapon, commonly used for self-defense and big prey hunting. It has a broad and long blade that surpasses 25 centimeters (9.842 inches) with a "clip point" type, which means it has sharp and manageable point, suitable for puncturing.

The one on one duel, known as the "Sandbar Fight" that took place in 1827 was where Jim Bowie, an adventurer, slave mercenary and land speculator, killed Major Norris Wright with one stab of his great knife, a present given by his brother *Rezin Bowie*. The event became well known because of the wide newspaper publicity. Jim Bowie died a couple years later on the epic Alamo battle in 1836.

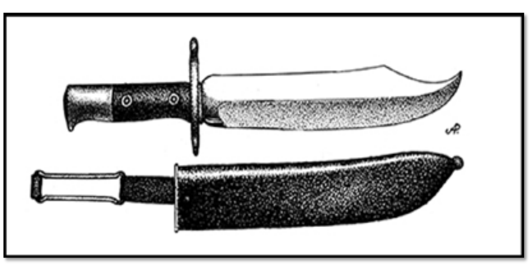


Figure 1. Bowie knife

In order to considerate our knife as a Bowie knife, the structure must fulfill the established historic parameters - previously mentioned in the beginning of this section- . Even though the features of the original Jim Bowie´s knife, are not fully known, because all the information that remains comes from stories and descriptions of people who attended the duel; however, as the years go by, the knife has adopted several features mainly based on movies and TV shows from the 50´s.

Conceptual Design

According to the Knife´s history and evolution, this tool has been used for survival and hunting until nowadays without losing its main style and morphology. As a survival tool, it must have a toothed blade that helps to cut at least a mid-sized trunk, see figure 2.

We decided to stick to the bases of this knife; however we added some aesthetic complements that improve its ergonomics and weight.

Figure 2. Bowie knife toothed blade

Detail Design and Manufacture

The design represents one of the most important processes in the fabrication of a Bowie Knife, because important features must be analyzed in order to avoid having problems and setbacks that could occur while manufacturing it as well as giving us a certain close image about how our knife would look like as a final product. In order to achieve the design and model of the Bowie Knife blade, we used the ***solidworks*** software as a tool that helped us analyze and digitally build the chosen design while verifying through simulation that it fulfills the established features of conceptual design and the requirements of the contest.

When we talk about casting, it is known that in order to get to the final product it is necessary to adapt the design to the requirements of the chosen process. The following image shows our final result.

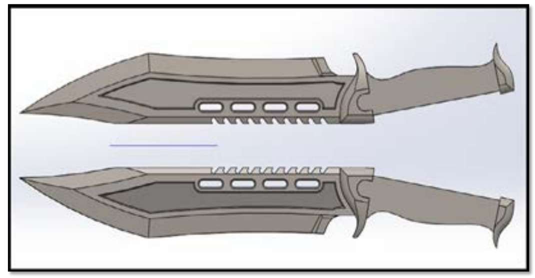


Figure 3. Final design

Once the desired geometry using the software is achieved, we proceeded to make the required modifications for its manufacture, that depend on the casting process, such as the pattern, the parting line of the pattern, drafts, surface finish, minimum wall thickness and stock material.

To obtain a better 3D printing quality, it was decided to divide the design in four parts in order to print them separately and subsequently joint them; the first cut made to the design was the blade cut: the blade was cut in half, as it is shown in the figures 4 and 5.

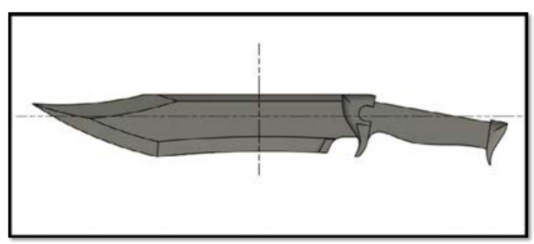


Figure 4. Design to 3D print

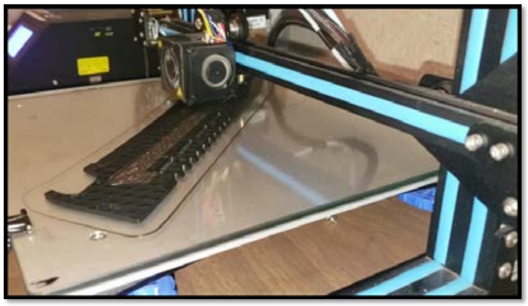


Figure 5. Printing the pattern

Hereinafter another cut was made leaving four parts ready be to printed separately, therefore the process took longer but the surface finish of the knife had a fascinating improvement as it is shown in the figure 6.

Figure 6. Printed pattern

When the printing process was finished, each of the knife pieces were bounded together obtaining one single piece, ready to be used.

Figure 7. Patterns ready to be used

Material Selection and Casting Simulation

There are plenty of materials we could have chosen for the final fabrication of our knife in order to obtain amazing results. That is why this part of the project was such an important factor to achieve our goal.

Among the variables we considered in order to choose the most appropriate material for the manufacturing, one of them was the mechanical properties, as this is crucial for the process, because if the final product does not meet the requirements it will be useless.

In order to adapt to the company´s possibilities and obtain the mechanical requirements for the fabrication of the Bowie Knife, we determined to use a martensitic stainless steel with high hardness, regularly used in Fundidora Morelia. This steel is the CA40 and it was chosen because *we won last Cast in Steel competition*, besides it has a high level of corrosion resistance and due to its high level of carbon concentration, the hardness values can reach up to 500 *Brinell* depending on the heat treatments applied.

Cr	11.5 - 14 %
Si	1.5 %
Mn	1 %
Ni	1 %
Mo	0.5 %
C	0.2 - 0.4 %
P	0.04 %
S	0.04 %

Figure 8. Typical chemistry

Once the material was defined, we proceeded to make the simulation of the solidification using the software ***"SolidCast 8"*** which allowed us to simulate the behavior of the steel while solidifies, by analyzing different criteria of the cast process, it showed the possible defects in the casting during the solidification of the material. We started with a 3D model and as a first step we had to know how many areas will need a riser to compensate the material shrinkage. Once those areas were identified we could continue with the calculations to know what height and diameter the risers must be so the module was bigger than the casting.

Afterwards, we used *Inventor software* to generate the rigging system, based on the calculated dimensions in ***SolidCast software;*** it is extremely important to place the risers correctly over the areas where the steel will change its density, until the last moment of solidification, so that we can avoid defects. One of the most important criteria in solidification is the "**critical fraction of solidification time**" that takes into account changes in the fluidity of the metal before solidifying completely.

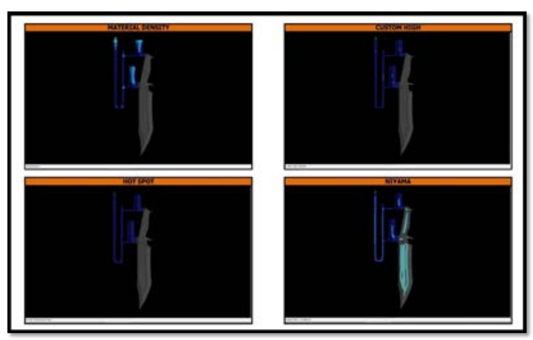


Figure 9. Simulation results criteria from SolidCast software

The idea of simulating a part before its casting is to perform different iterations so that we can find the best possible way to manufacture it to avoid negative factors, as shown in the figure 9. In some cases, although the pattern is designed to obtain a mold in some specific position, that pour position is changed to improve casting.

The dimensions of risers, chillers, pads, sprue and other elements are drawn in their correct position so that they can be modeled and thus obtain a final mold according to the final simulation. For the realization of the mold it is important to respect all the dimensions of the runners, gates and sprue, to avoid having a pressurized system, which prevents the mold from deteriorating by the high speeds of the metal.

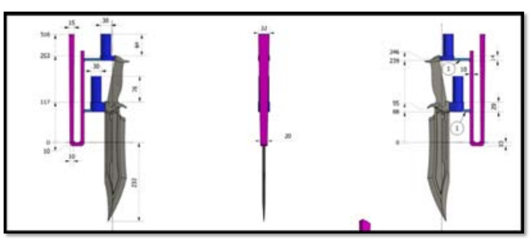


Figure 10. Rigging system design

An important factor to consider in casting and simulation of it is the riser position. It should not interfere with the aesthetic details of the blade and the shape work already done, since it could ruin everything. Within the tools of the simulation software, there is a section dedicated only to the analysis of metal flow through the mold to be able to easily visualize unwanted behavior in the flow of the molten material or just simply verify that its operation is as expected.

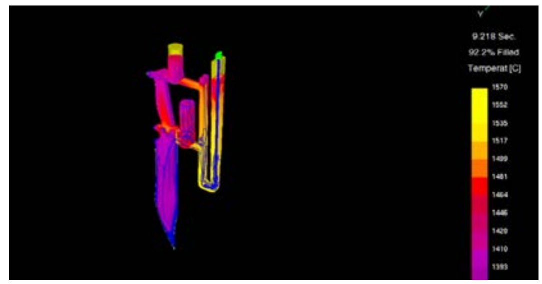


Figure 11. FlowCast module

Molding and casting of the Bowie Knife

There are different molding processes for castings, Fundidora Morelia uses No-Bake process, and it is the only one used for molds and cores. It is so good for castings and parts relatively large where small surface details are not important. Molds for Bowies were manufactured using this process, but details in the patterns were omitted due to this process.

Another molding process capable of giving good results in casting surfaces small details is the investment casting process. Fundidora Morelia does not have this process but it was suggested by them to get some shells from another foundry which has this process and then pour the shells together with the molds already made of No-Bake. The intention is to pour the Bowies using both processes, then work with them and deliver the better one.

The investment casting process for the shells manufacturing also known as lost-wax casting consists of:

1. Wax injection to obtain the patterns: For our specific case the pattern will be made using PLA instead of wax since the pattern was fabricated with the help of 3D printing.

2. Clusters or skeletons of pattern in PLA, are put together to get 2 castings in one shell.

Figure 12. Two PLA patterns put together in one shell

3. Refractory coating is applied (fine grain); which is achieved by two or three dives of the clusters in the refractory paste which consists of zirconium oxide (sand), although other refractory materials such as gypsum, magnesite, silimanite can be used depending on the alloy, temperature of the molten metal or the intended purpose.

4. On top of the ceramic coating, fine sand is sprinkled which provides a proper bonding with the back filling.

5. Coating and filling with coarse-grained sand, provided with binder done by vibration. The purpose of this filling is to provide stability in the shape of the fine-grained inner layer.

6. The wax is taken out of the shell.

Figure 13. The wax is melted and drained

7. The shells are placed into a furnace to complete drain out the remaining wax and PLA and finally reach the best temperature before pouring.

Figure 14. Shells ready to be burned

The second molding method employed was alfaset. It is a No-Bake phenolic ester cured system this in order to make different knives and find the best process for the final design, and obtain the highest quality possible. This method consists of making 2 halves that together will make the mold, to achieve this we must create a two-part pattern that in this case was made of PLA like all other designs.

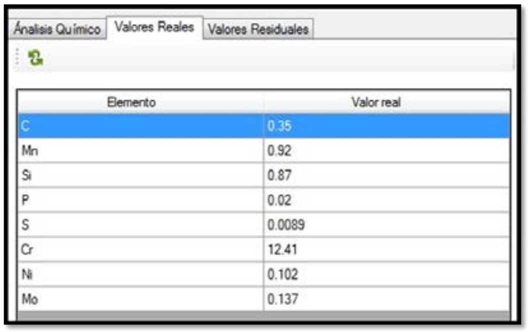
Figure 15. No-bake mold faced with ceramic sand.

Figure 16. Cope and drag molds washed with zircon wash coating

Figure 17. Nine knives and 3 different designs were made

These both processes can be seen in the manufacturing video.

To prepare the heat it is necessary to add the quantities of elements needed to the induction furnace in order to obtain the right amounts of chemical elements to achieve a stainless steel type CA40. To verify that the material had the correct chemical composition before pouring, an optical emission spectrometer was used. This device calculated the percentages of elements present in a sample extracted from the furnace. The figure 18 shows the actual chemical composition of the heat.



Análisis Químico | Valores Reales | Valores Residuales

Elemento	Valor real
C	0.35
Mn	0.92
Si	0.87
P	0.02
S	0.0089
Cr	12.41
Ni	0.102
Mo	0.137

Figure 18. Actual chemistry of the Bowies' heat

Having all elements in accordance with the standard, we can proceed with the pouring of the heat.

Before casting pouring, the molds were previously preheated to a temperature of 1100°C (2012ºF) so that there was no thermal shock when pouring the molten metal into the molds. We can see the preheated shells being placed and prepared to pour the material in figures 19 and 20.

Figure 19. Pre-heated shells

Figure 20. Shell placed to be poured

8. Pouring, solidification and cooling, shake-out.

Shake-out and post-processing

Once the material was completely poured into the molds and shells, they were left to solidify in about an hour and a half to shake-out the knives, after this they were left to cool down for an entire day to be able to perform the necessary heat treatments and tests.

Figure 21. Shake-out

Heat treatments

The heat treatment was accomplished by heating the Bowies to a temperature of 890ºC (1,634 ºF) followed by quenching the blades in oil to increase the hardness of the material as shown in the figures 22, 23 and 24.

Figure 22. Bowies removed from the furnace to be quenched

Figure 23. Blades quenched in oil

Figure 24. Bowies after quenched in oil. Note that only the blade was quenched

After quenching, they all were tempered to 390ºC (734ºF), obtaining a hard material without losing tenacity in the same one.
Knowing that the blade of our knife is in good condition, the only thing left in the manufacture of the Bowie is to sharpen the blade and improve the aesthetics for its presentation; some surfaces were polished and others left a gray hue to contrast with the brightness of the metal. The blade then was weighed to be verified by making a comparison between the approximate weight of the CAD design and the real one, having only a small variation between the calculated and the obtained weights.

We can conclude that a good work was done to design and manufacture our Bowie Knife.

Final assembly

As the last step of this project the hilt made of resin was placed, there were special brass rivets manufactured on a lathe to improve its aesthetics, the hilt was sanded to give it the most ergonomic and easy to grip shape, it was polished until the resin and steel were shiny.

Figure 25. Finished Bowie Knife