Cast in Steel

Casting a Bowie Knife (Hints That May Help)

A Bowie knife could be a net-shape sand or investment casting.

Sand casting

The challenge of casting a Bowie knife blank in sand molds is to get the detail and thin section desired. There are a number of tricks that may be helpful. *SFSA Research Report No. 113, Fillability of Thin-wall Steel Castings,*[1] explored the challenge of casting thin sections in steel.

[1] *To request a copy of SFSA RR113, email Diana David, ddavid@sfsa.org*

Making a casting wall thickness 4mm or greater is well within normal practices, especially with a short fill distance. If you try to fill the knife from the end of the tang to the point, that would be difficult. Filling through the guard would improve the ability to fill the casting. A common strategy would be to cast the blade horizontally with a gate/riser on the top of the blade with several gates or even a continuous *knife gate*[2] down the length of the blade from the top. You could even go to the extreme of putting the knife casting on the bottom of a cast block to get feeding and filling – the cast block on the top would force the metal into the thinner section (knife) ensuring solidity of the part cavity (knife).

[2] **Definition:** *A "knife gate" is not related to the Bowie knife but is instead a foundry term for using a thin and long gate where the metal would enter the part cavity in the mold*

One challenge of thin sections is controlling the thickness of the mold cavity. If the mold cavity is two sand core or mold pieces, the uncertainty of location is typically 1mm and for a 4mm wall tapering to 1mm, a 1mm loss of location means the cast blade mold cavity may be too thin to fill. A couple of options to resolve this would be to carefully inspect and assemble molds or to machine or print molds.

Another challenge can be thin section casting properties, which are typically limited by the cleanliness of the steel. Clean steel refers to the contaminants in the steel such as phosphorus, sulfur, and other tramp elements such as tin and antimony, gases such as hydrogen and nitrogen, *reoxidation inclusions*[3], and foreign materials entrapped in the steel such as refractory material from the furnace or ladle, slag, sand or other mold material. Clean steel starts in the furnace – use good, quality scrap and follow proper melt practices to minimize reaction with atmospheric gases.

[3] **Definition:** *Reoxidation inclusions are the byproduct of the reaction between elements in the steel and oxygen after the molten steel has been deoxidized. Oxygen can come from the air, slag, or refractory.*

Good melting practice should be accompanied by good tapping and pouring practices. Careful handling of the steel not just during melting but also during every step of the casting process is key to getting high performance steel properties. Filters or careful gating can be used to manage the flow (filling of the mold). Filters can help keep molten steel clean by trapping inclusions during filling. The design of a good gating system or rigging, use of risers to float out inclusions, are common foundry tricks for minimizing inclusions in castings. Thus, the filling of the mold in general is an important consideration.

Filters or complex gating may slow the speed of fill, which is the most important tool to get filling. Higher filling velocity is the primary way to get thin sections to fill. Putting the knife's thin edge vertical in the mold with a side gated block above it would be one strategy. It might be attractive to put the point down and have the blade vertical up the side of the gate/riser or block to get filling. Solidification and filling modeling will help in the design. Note, pour height can increase velocity but increased velocity can negatively affect steel cleanliness if it entrains more air increasing reoxidation of the steel. Also, the more area where the molten metal and air can react increases reoxidation. A tall, tapered sprue can be used for maximum velocity and fill, but this also does not resolve the propensity for reoxidation nor potential issues of a high velocity stream entering the mold cavity, which can result in molten steel spraying into the cavity. The use of a naturally pressurized gating system is one option to manage filling and help promote clean steel.

It might be useful to make alternative mold designs and pour them from whatever alloy is being produced at your foundry partner to validate the gating and filling before producing your final mold design. Note, this will require working with the foundry and planning with enough time for multiple pours. Using Additive Manufacturing to print molds or patterns (tooling) provides a cost-effective options to try multiple mold designs, and can offer additional freedom of rigging (gates/risers) design.

Investment casting

Commercial cast knives are made in the investment process.

Investment casting makes the production of detailed features and thin sections of the knife casting easier. The shell is pre-heated to around 1800°F and so filling is straightforward. There are multiple opportunities to use Additive Manufacturing for investment castings (SLAs, printed or machined wax patterns, printed ceramic shells, etc.), which would allow several design variants to be tried if desired.

A challenge is to ensure the investment casting is sound and has good mechanical properties. The preheated shell can promote slow solidification and this cooling can limit the properties of the blade. Chills can be effectively used with sand castings to promote rapid solidification, create fine grains, and drive directional solidification; however, the use of these chills in investment casting doesn't work due to the pre-heating of the shell. One method of optimizing the properties is to direct fans or otherwise cool the shells after pouring to accelerate the cooling. Two or three austenitizing heat treatment cycles of normalizing and austenitizing will help improve the properties but may not provide the best results. Note, multiple heat treatment cycles may result in scale reducing the desired thickness of the blade.

One challenge may be making the investment casting sound. Unlike sand castings, typical investment castings are not risered and depend on the gate and “tree” (sprue) to act as a riser. The heat transfer from the casting during solidification is driven by the loss of heat from the shell (sand mold solidification is from the loss of heat to the mold). Whether for an investment or sand casting, the use of Hot Isostatic Processing (HIP) may be leveraged to close small internal shrink, which would also include microporosity (a key driver of fatigue or high performance properties).

Finishing

The casting does not need to be the finished blade, the competition is using the casting process to add value and innovation. The knife blade will need to be finished by grinding, sanding, machining, etc. SFSA is doing a project using forging on cast features to improve properties locally. You could forge the edge to get the optimal properties. You could cast steel around a steel insert to get a composite structure. You could start with a centrifugal casting. Again, innovation for using a steel casting is the key (steel casting should drive the design, engineering, and resulting performance to meet the competition objectives).

Finally, your partner foundry will be a terrific resource. They can help you vet innovative ideas on mold design as they’ve been doing it for years.