MOLD MAKING FOR ROTATIONALLY MOLDED PLASTICS PRODUCTS

Peter W. Klein, Ph.D.
klein@ohio.edu
Department of Industrial Technology
Ohio University

ABSTRACT

Rotational molding, also known as roto-casting and rotomolding is a process widely used in the plastics industry to create a variety of products with minimal molded in stress and a hollow, seamless geometry. These parts range in size from a small toy ball the size of a ping-pong ball up to agricultural tanks holding over 25,000 gallons of liquid. [1] Molds can be produced in a variety manufacturing processes including: casting, machining and fabricating. This paper will discuss mold making using the dry sand casting process to cast aluminum as well as wood and plaster pattern making. The example used in this paper was a project developed by a student and their Professor to make clubs for juggling. In this example the students had an opportunity use various materials (wood, plaster, aluminum and polyethylene) and a variety of manufacturing processes (wood laminating and turning, plaster casting, dry sand aluminum casting and machining) while producing a high quality mold for class use. This was an excellent project for the student to apply knowledge gained in various courses.

Specific Learning Objectives include:
1) The student will understand the process to produce a wooden model.
2) The student will understand the process of producing a foundry pattern using tooling plaster.
3) The student will understand the dry sand foundry process.
4) The student will be able to explain how material shrinkage relates to part and mold design.

I. INTRODUCTION TO THE ROTATIONAL MOLDING PROCESS

The fundamental process of rotational molding involves rotating a closed mold, typically aluminum, in a biaxial motion inside of an oven. The thermo-plastic material, typically in powder form, is tumbled inside the mold where it becomes tacky and adheres to the hot surface of the mold and eventually the powder fuses into a solid mass coating, but not adhering to, the mold interior. It should be noted that this process is limited to materials that are capable of being pulverized into a fine powder, flow like a liquid (in powder form) and fuse into a solid mass without pressure. Liquid plastics such as vinyl plastisol may also be used in this process as they too will flow and fuse. [2] The mold is then cooled and the plastic solidifies and is removed from the mold. It is not the intent of this paper to discuss in details the rotational molding process, but is rather focused on the mold making process.

II. PART DESIGN

Juggling clubs come in many sizes and shapes but there is a common geometry among all designs. The handle tends to be long and narrow while the body is much larger in diameter. This difference allows the clubs handle to rotate around the larger mass of the body allowing the juggler to easily grab the handle while the club is spinning. Clubs may be sculpted by an artist or engineered using CAD/CAM systems. During this project we chose to review currently available clubs for general size and shape configurations. We then documented our design using Solid Edge as indicated in Figure1. This drawing became the final design for the wooden model to be produced on a wood turning lathe.

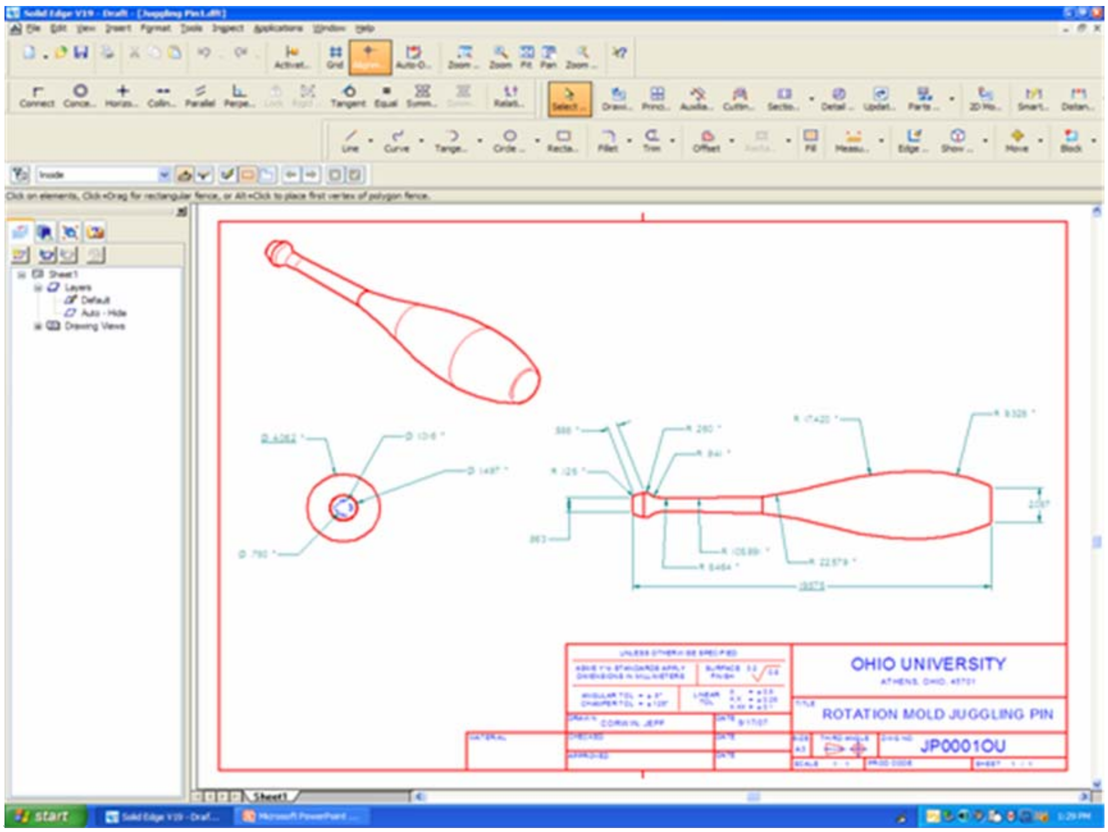

Fig. 1 Solid Edge Part Drawing

III. MODEL MAKING

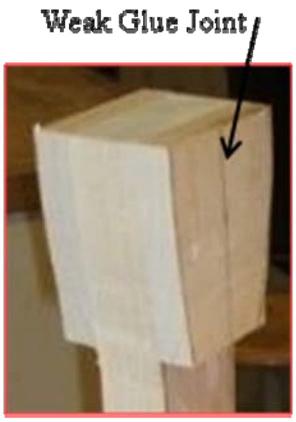

Fig. 2 Poplar Laminate

Once the design for the model had been produced, material was selected and prepared for the lathe turning process. Poplar wood was selected due to its closed grain structure and ease of machining characteristics. [3] Wood was selected that was free of defects such as knots and checks and pieces were cut to be assembled to produce the model. As indicated in Figure 2, paper was glued between the two center boards to create a weak glue joint to enable the model to be split in half after it is produced. [4] The pieces were arranged, glued and clamped for 24 hrs to assure excellent curing of the glue. Wood turning on a lathe can create high forces which can break the laminate apart and possibly cause injury to the lathe operator so it is imperative the the glue joints be properly clamped and have sufficient time to cure.

Once the laminate has cured overnight, the clamps were removed and the laminate was roughly cut to size on a band saw as indicated in Figures 3 & 4. The ends were then marked for the centering process to mount the laminate on the lathe between a live center and dead center.

Fig. 3 Rough Cutting Laminate

Fig. 4 Rough Cut Laminate & Purchased Club

The laminate was turned to the desired design using traditional wood turning techniques and was continuously checked to verify the shape conformed to the drawings. (Figures 5 & 6)


Fig. 5 Rough Cutting Model

Fig. 6 Model Turning

Once turned to the desired shape of the model, the part was sanded very smooth using progressively finer abrasive paper as shown in Figures 7 & 8.


Fig. 7 Sanding Model

Fig. 8 Completed Turning

A wood finish was applied to seal the wood and improve the surface finish. (Figure 9) It should be noted the surface finish will be replicated exactly in the tooling plaster so the model finish was critical to create a quality casting. In this case wood sealer was applied in several coats followed by several coats of wax. (Figure 10)


Fig. 9 Applying Sealer

Fig. 10 Complete Model

Once the wood finishes have cured, the model must be split in two. Since a weak joint was planned by gluing paper between the two center boards, this process is quite simple. A sharp, thin chisel was aligned with the weak glue joint and is driven into the joint with a hammer, which splits the model along the weak joint. (Figures 11-13)

Fig. 11 Splitting Model

Fig. 12 Splitting Model

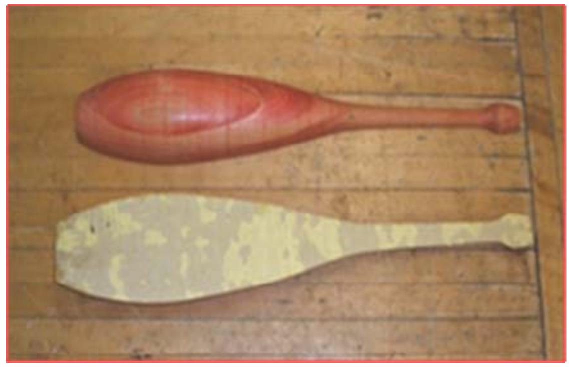

Fig. 13 Split Model

IV TOOLING PLASTER PATTERN MAKING

Tooling Plaster (US Gypsum Ultracal 30) is a "super-strength gypsum cement recommended where extreme accuracy and great surface hardness are required". [5] Tooling plaster has been used for centuries in the pattern making industry. It is extremely hard and dense and will replicate fine detail from whatever surface it is cast against. A framework was built around the model halves to hold the plaster while it cures. (Figure 14) The plaster is mixed in a way to reduce air bubbles, then poured over the model halves and allowed to cure. (Figure 15)

Fig. 14 Model Ready for Plaster

Fig. 15 Pouring Plaster on Model

Once cured the plaster pattern was removed from the model. (Figure 16) Using basic woodworking hand tools such as a coping saw and file, the large pattern is reduced in size to create the proper pattern for the foundry. (Figure 17)

Fig. 16 Cured Plaster Pattern

Fig. 17 Rough & Finished Pattern

V. CASTING THE ALUMINUM MOLD

Sand casting of metals goes back to 4000 BC. [6] The dry sand casting process uses a pattern, in this case our plaster pattern, to create a void or cavity in the sand which was then filled with molten aluminum. When the aluminum cools, the sand was removed leaving a detailed aluminum replication of the pattern. [7]

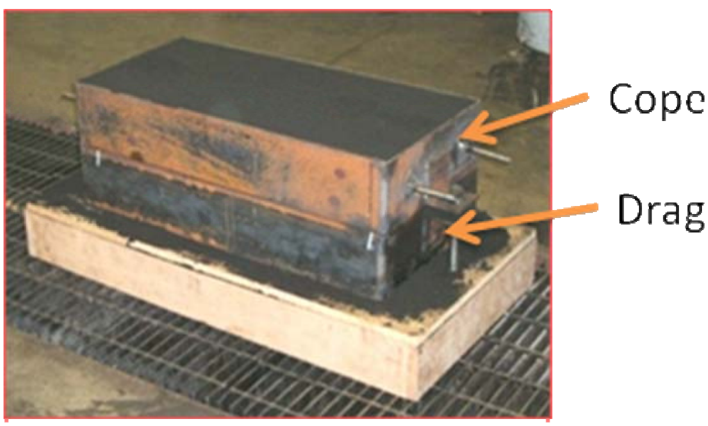

Fig. 18 Flask

The dry sand mixture, casting sand with a petroleum based binder, was packed around the pattern to create the cavity. This was done in a metal framework called a flask. (Figure 18 & 19) A sprue was cut in the sand which was the location that the molten aluminum will be poured into the sand mold. A riser is also cut into the sand which will allow gasses to flow out of the mold cavity as well as supply a reservoir of aluminum for the part to draw from during cooling; this will reduce some common molding defects. (Figure 20)

Fig. 19 Packing Sand Around Pattern

Fig. 20 Cutting Sprue & Pouring Basin

The flask was then opened to remove the plaster pattern. (Figure 21) The top half of the flask, know as the cope, was set aside. This half has the sprue and riser already cut in place. The pattern was removed from the bottom half of the flask, known as the drag, and a runner and gate was cut into the sand to connect the sprue to the cavity. (Figure 22) Another runner was cut to connect the riser to the cavity.

Fig. 21 Opening Flask

Fig. 22 Cutting Runner & Gate

The cope was placed back on the drag and the mold was ready to receive molten aluminum. The aluminum was melted in a kiln to a temperature of 1225 degrees F. [8] (Figure 23) and poured into the sprue until it can be seen in the riser, indicating the mold has completely filled with aluminum. (Figure 24)

Fig. 23 Melting Aluminum

Fig. 24 Pouring Aluminum

The casting was allowed to cool overnight before the flask was opened and the sand broken off of the part showing the rough casting which will become the juggling club mold. (Figure 25)

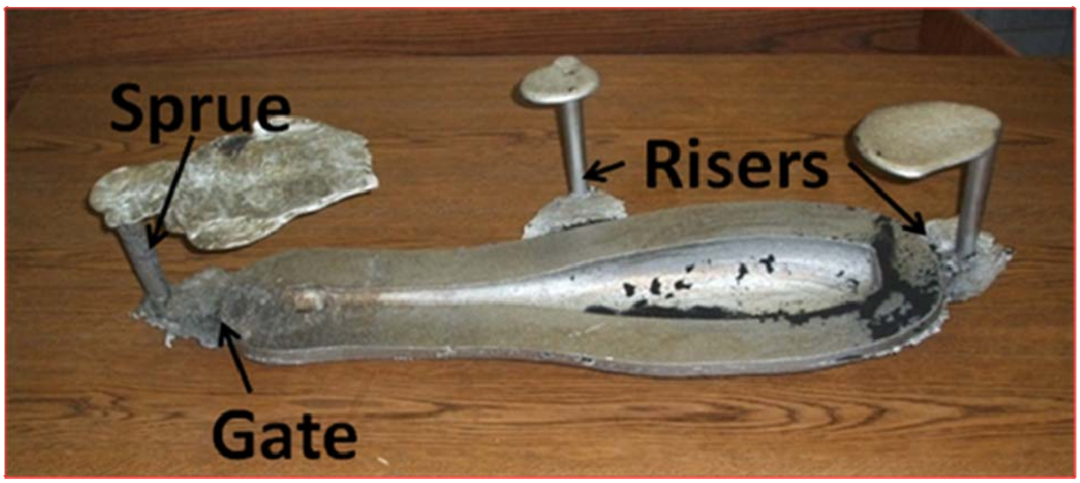

Fig. 25 Rough Casting

VI MOLD FINISHING

The aluminum casting as is it was removed from the sand was quite rough and has the sprue and riser/s still attached. However, a successful casting must have a good finish on the inside surface which will be used to produce the plastic part. The finishing process includes several steps:

1. Removing the sprue, gates and riser/s typically with a band saw.
2. Truing the parting line surface to produce a flat parting line between the mold halves to trap the powered plastic in the mold during rotation.
3. Filling and repairing any surface defects on the mold interior using suitable filler such as JB Weld which can handle the molding temperatures. (Figures 26 – 28)
4. Aligning the two mold halves to create a smooth parting line on the part, then drilling holes to connect the two halves in perfect alignment. (Figure 29)
5. Smoothing the rough edges of the casting.

6. The final finishing step is to apply the mold texture, most commonly a sand blast finish on the interior of the mold.

Fig. 26 Casting Defect - Porosity

Fig. 27 Filler for Porosity

Fig. 28 Removing Filler – Smoothing Mold Surface

Fig. 29 Machining Holes

VII MOLD TRYOUT

As with most new molds, a mold tryout was performed to check the mold performance. Before using the mold for the first time, it was treated with a suitable mold release agent to assure the melted plastic, in this case high density polyethylene (HDPE), will not adhere to the mold surface. There are varieties of products made for this specific purpose. One of the first issues when testing a new mold is to determine how much material to use. Since all material placed in a rotational mold will become the product, one option was to estimate the desired weight of the juggling club. We first weighed a commercially made juggling club and compared its size to our design. Since our product was larger, we increased this amount slightly to give us a starting point. This amount of material was placed in the mold and the mold was bolted closed.

The mold was then secured in the rotational molder; in this case we used a Ferry M 20 Clamshell machine as shown in Figure 30. Since we chose HDPE for our material, we needed to determine the proper machine set up data. The critical factor in the cycle is to have the material reach and hold its optimal processing temperature for the appropriate amount of time. This will create the best “cure” of the part which means the plastic powder has fully fused with no air bubbles trapped inside of the wall section. This will also produce the greatest impact strength of the part. As noted earlier, it is not the intent of this paper to discuss the rotational molding process in detail. The paper is focused on mold build rather than the molding process. It was determined that the optimal internal mold temperature would be between 220 and 240 degrees C (428 – 464 F) for 10 minutes. [9] This proved to be an acceptable processing parameter given the part quality that was achieved.

Fig. 30 Ferry M20 Clamshell Rotational Molder

VIII PART QUALITY

One of the biggest concerns about this project was material shrinkage. It was assumed that plaster, aluminum and HDPE all would shrink resulting in a significant change in size from the original wooden pattern to the completed HDPE part. Figures 31 & 32 show the dramatic shrinkage of HDPE during the molding process. There are many variables that affect part shrinkage including part thickness, processing temperature range and part cooling time. Common mold shrinkage (the difference in dimensions of the mold and the molded part) for HDPE is 3%. [10] Per the Shrinkage Table below, the actual mold shrinkage was about 2% in length and less than 1% in part width. The aluminum also exhibited shrinkage as it was smaller than the plaster pattern. The aluminum showed 0.6% shrinkage in length and over 2.3% in width. The common pattern shrink allowance is 1.3% for pattern makers. [11] It must be noted that the tooling plaster showed no measurable shrinkage which makes it an ideal pattern making material. The total shrinkage from wood pattern to HDPE part was 2.5% in length and 3% in width. This "real" data will be useful when designing future products for rotational molding.

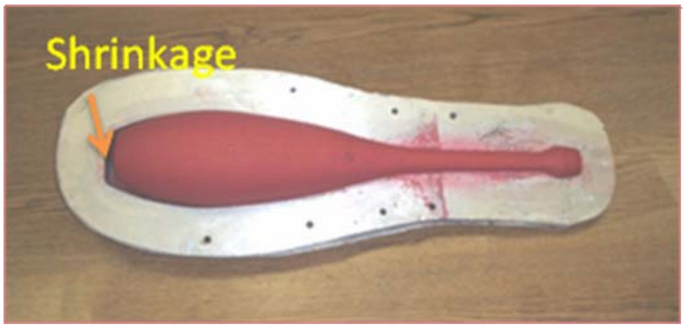

Fig. 31 HDPE Part in Mold

Fig. 32 Part Shrinkage

Shrinkage Table

	Wood Pattern	Plaster Pattern	Aluminum Mold	HDPE Part	Total Shrinkage
Length	19.875"	19.875"	19.750"	19.375"	.500"
Width	4.0625"	4.0625"	3.9687"	3.9375"	.125"

IX CONCLUSION

This project was an excellent method to tie together many skills gained in different classes into a unique, and fun, learning activity. The student had to evaluate current products from a design perspective, and then apply their insight to their own design using Solid Edge CAD software. Once the design was determined the model building process had to be determined including the processes and materials to use. Since wood turning is not part of the curriculum, the student had to study this process and make some practice parts before attempting the model build. Laminating techniques were studied that would allow the model to be precisely split in the center to produce two halves. A new material and process for making the foundry pattern had to be studied. Although tooling plaster had been used for centuries, it is typically not studied in our materials courses. Students do have an opportunity to perform some dry sand aluminum casting but had never used a fragile, thin pattern. The casting process was actually the most time consuming. The student first had to design and build a flask suitable for this large product. Because of its size, the mold was very heavy and would often collapse from its own weight. Four successful castings were required to produce two molds. To produce these four castings required at least ten attempts to produce a good casting mold in sand. The students also learned the true impact of material shrink rates and had an opportunity to compare their actual results with the charts produced in textbooks.

In summary, the mold design and construction was an excellent learning experience for the students as well as the faculty member. They had the opportunity to use multiple materials including wood, tooling plaster, aluminum and polyethylene. They also used many processes including a variety of woodworking processes, aluminum sand casting, machining and rotational molding. Students also learned to appreciate the precision work performed by model makers and tool makers. The best part about this activity is the end result, a high quality juggling club that is a unique design created by the student which can be mass produced as seen in Figure 33. Figure 34 shows a finished set of three clubs with decorative tape applied as well as tape on the handle to enhance the jugglers grip.

Fig. 33 Molded Club

Fig, 34 Complete Set of Clubs

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