Design and Injection Molding of a Skateboard Wheel

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Introduction

Skateboarding is an extremely popular activity that people around the world enjoy. Due to the nature of the skateboard itself, one of the most integral parts is the wheel of the skateboard. Many people overlook the importance of choosing the correct wheel design and material for the applicable style of riding. The main manufacturing technique of skateboard wheels is injection molding of thermoplastic polyurethane (TPU). In an industrial setting, a large injection molding machine with relatively unlimited parameters and shot size would be available to make multiple wheels at once. However, in the lab setting, there are limitations to machine size and capabilities. In this report, the design of a wheel, creation of a mold, and simulation of injection molding parameters are investigated to successfully manufacture a skateboard wheel on the APSX PIM machine with limited capabilities.

Wheel Design and Material Selection

The inspiration for this design comes from my inability to be able to learn how to skateboard during my childhood. Growing up in Alaska, the roads always had divots and cracks and the sidewalks were covered with pebbles. This would usually call for the use of a large wheel with a 60+ mm diameter and a very large riding surface. However, another environmental constraint of Alaska's pavement is that there is never really a flat surface to ride on. Every to-be riding surface would either be slanted or covered in divots as mentioned above. This will cause the board to always be leaning and having a larger wheel would increase the chances of wheel bite, where the deck of the skateboard will contact the wheel while riding (Skate Warehouse, 2022). Taking in all the environmental obstacles that Alaska has, the chosen design mostly represents a conical wheel shape. The material of the wheel was chosen to be TPU with a shore hardness of 82A. This was chosen to be able to compensate for the smaller wheel size and the availability of this polymer. Having a shore hardness of 82A allows for the wheel to absorb the strain that comes from running over defects and obstacles on the riding surface, allowing for a smoother ride and fewer accidents (Warehouse Skateboards, 2022).

The wheel itself has an overall diameter of 55 millimeters with an overall thickness of 30.50 millimeters. The riding surface of the wheel is 20.50 millimeters, and this is achieved by using a chamfer going toward the riding surface by 10 millimeters and going towards the center of the wheel by 17 millimeters. These parameters resemble a mixture of the popular Spitfire Radical Slim Wheels and the Spitfire Conical Wheels (Slam City, 2022). One of the restraints of the APSX PIM is that it is limited to a shot size of 30-35 cm^3, assuming the runners and gates add a negligible amount of volume. To meet this constraint, numerous cutouts were used to reduce the volume of the wheel to about 29 cm^3. The two cutouts of significance are in the bulk of the wheel and where the bearing is held. Most of the material in the bulk of the wheel (area between bearing and riding surface) was cut out to decrease the volume of the wheel. These cutouts leave a thickness of seven millimeters on the riding surface, which is theorized to be enough to avoid catastrophic failure of the wheel. The bearing is held in a hole with a diameter of 22 millimeters and a depth of seven millimeters. This allows for the bearing to have a tight fit and be completely set into the wheel. What is different from a traditional wheel is the backing for the bearing is cut up into eight chunks. This allows for even more volume to be cut out of the design as well as acting as eight built-in injection points/runners. The design is further highlighted in figure 1 and figure 2.

Figure 1: Wheel Render from Above

Figure 2: Wheel Rendering from the Side

Mold Design

In the mold, there was no need for anything other than a sprue runner. This is because the best possible method for filling the mold is by having the injection from the center of the wheel out. This allows for the utilization of the sectioned extrusions in the middle of the design as highlighted in the previous section and figure 1. The wheel was offset to have more of the wheel be in side B of the mold. This will cause the wheel to be stuck in side B once the process is completed so that the ejection pins can be utilized; 60 percent of the wheel ended up being located in side B in the final design.

Two sizes of gates were utilized in this mold, one for the larger injection points and one for the smaller injection points. During this report, the gates for the larger injection points will be referred to as primary gates and the gates for the smaller thicker will be referred to as secondary gates. Both gates come directly from the sprue runner and go into the part, injecting the polymer from the center out. The primary gates have a depth of 2.4 millimeters and a width of 4.50 millimeters. This is because the part in which the primary gates feed is 6.06 millimeters thick which yields a depth 40% the size of the thickest part. The secondary gates have a depth of 0.8172 millimeters and a width of 4.50 millimeters. This is because the part in which the secondary gates feed is 2.043 millimeters thick which yields a depth 40% the size of the thickest part. The difference in gate sizes is highlighted in a rendering of side B in figure 2. All of the gates are mainly located in side B of the mold but have 1.650 millimeters protruding into side A, this is shown by the shallow cutouts where the gates are in figure 3.

Figure 2: Gates in Side B of Mold

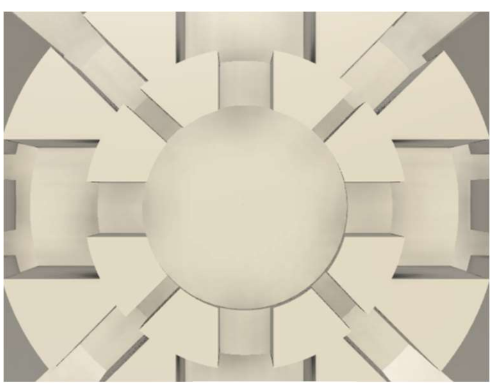
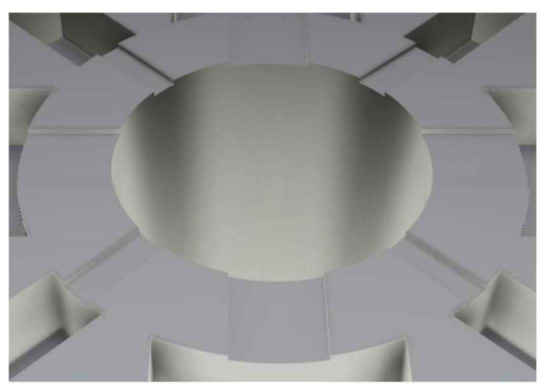


Figure 3: Gates in Side A of Mold



The ejector housing was cut out of the back of side B and was 75.55mm wide, 75.601mm in length, and 26.002mm deep. The mold features a 6.35 mm (1/4”) thick buffer plate in between the object cavity and the ejector housing. This allows for ample structural support from the mold itself so that support pins are not needed. The ejector plate itself is a 10 mm thick piece of aluminum with dimensions of 66.417 mm by 66.463 mm. The design features oversized holes for 2.50 mm ejector pins and 5.00 mm retention pins. The top of the ejector plate also has 5 mm deep countersinks to house the ejector pin heads so that the face of the plate is flush.

Figure 4: Ejector Plate Front

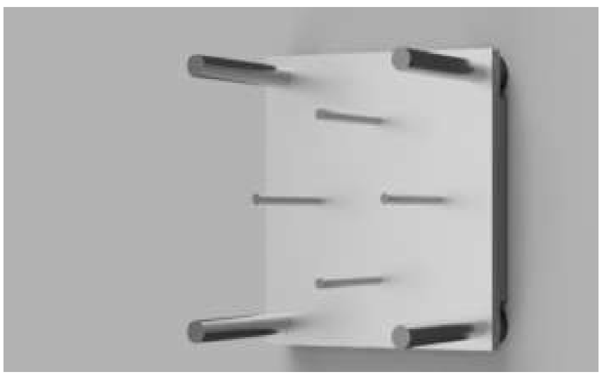
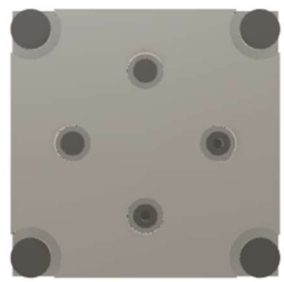
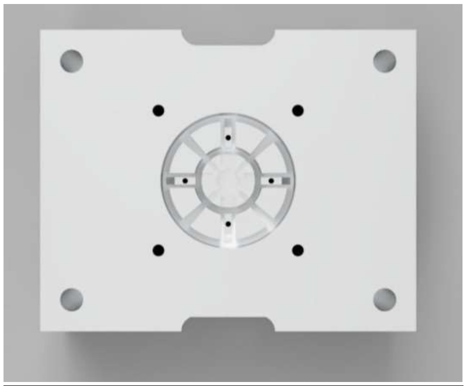


Figure 5: Ejector Plate Back



The location of the ejector pins was chosen to be on the thickest section of the wheel which has a flat surface. During the design process, a chamfer on the entire side of the wheel was needed to be able to reduce the volume of the part. This effectively eliminated the possibility of the ejector pins being used on the side of the molded part. Instead, one of the smaller cutouts in the thickest part of the wheel featured a flat surface that was perfect for ejector pins. Since this location was in the middle of the wheel and on one of the thickest parts, only four ejector pins were needed to efficiently cycle this mold.

Figure 5: Mold Side B with No Ejector Pins

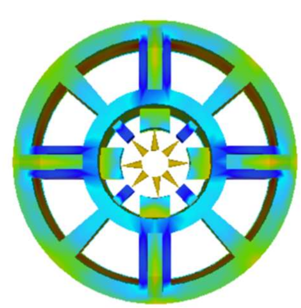


Injection Parameters

Three injection molding simulations were run in Fusion 360. All three had eight injection points that modeled the eight gates which are present in the model. In the simulation, the polymer used was the Lubrizol Pellethane 2103-80AE TPU (shore hardness 82A). The material data sheet for a similar polymer by this company was found online and it suggested a melt temperature of 182-210 centigrade and a mold temperature of 16-60 centigrade (Lubrizol, 2018). When these parameters were used in the second simulation, the study yielded a 100% confidence to fill which was a surprising but welcomed result. It also featured no shrinkage where the bearing sits, so there will be no tolerance issues when attaching the wheel to the board.

Figure 6: Injection Molding Fill Confidence

Figure 7: Injection Molding Shrinkage



One of the limitations of the APSX PIM machine is that the maximum injection pressure that the machine can obtain is 34.5 MPa. This would usually be a problem for most injection molding parts, but surprisingly this is not a problem for this wheel. After looking through the data in the simulation, it was found that the maximum pressure that the mold filling required was only 29.8 MPa which is well within the capabilities of the machine. Using Fusion 360's ability to calculate optimal filling and cooling time, it was found that the filling time using these parameters was 0.20 sec, with a packing time of 5.47 sec, and a cooling time of 46.47 sec. This would yield an overall cycle time of 52.14 seconds. Ways to decrease the cycle time will be discussed in the scale-up section later in this report. Below is a table of the theorized injection molding parameters.

Table 1: Injection Molding Parameters

Barrel Temp (C)	210
Mold Temp (C)	60
Inject Pressure (MPa)	34.5
Hold Pressure (MPa)	5
Clamp Force (Kg)	3000
Hold Time (Sec)	5.47
Cool Time (Sec)	46.47
Clamp Time (Sec)	0.20

Cut Off Amount (cm^3)	40.0
First Stage Amount (cm^3	13.0
Valve First Position	180
Valve Second Position	200
Hopper Multiplier	180
Hopper Speed (1-20)	20

Scale Up

For scale up of this mold, the sprue would be in the same place going into the wheel. Injecting the polymer from the center out has been proven to provide a sufficient method of getting a complete fill of the mold. However, instead of going straight from the sprue gate to the mold, there would be a series of runners that would feed into the wheels in multiples of two. There would be one primary runner that runs the length of the mold and secondary runners going from the primary runner to the sprues that feed into the parts. The ejector plate configuration would either be the same for each model as they were in this study or there would be one large ejector pin for each wheel. Liquid cooling would also be added to make the cooling process and, therefore, the cycle time quicker.

Conclusion

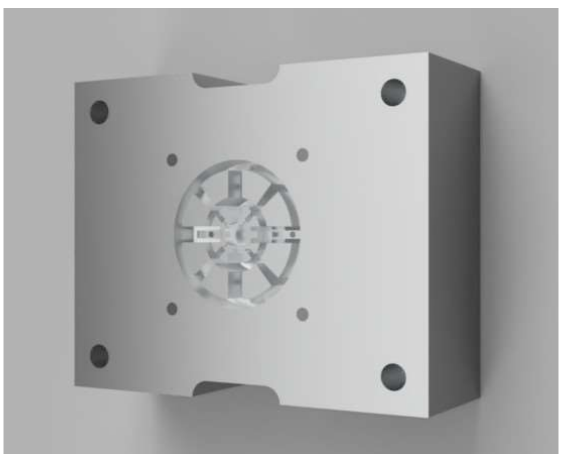
Overall, the design and creation of a skateboard wheel via injection molding was a success. The wheel was able to be cut down to a shot size of 29 cm^3 which allows it to be injection molded on the APSX PIM machine. Furthermore, when using TPU with a shore hardness of 82A, a complete injection fill was achieved by using an injection temperature of 210 centigrade, a mold temperature of 60 centigrade, and a maximum injection pressure of 29.8 MPa (298 Bar).

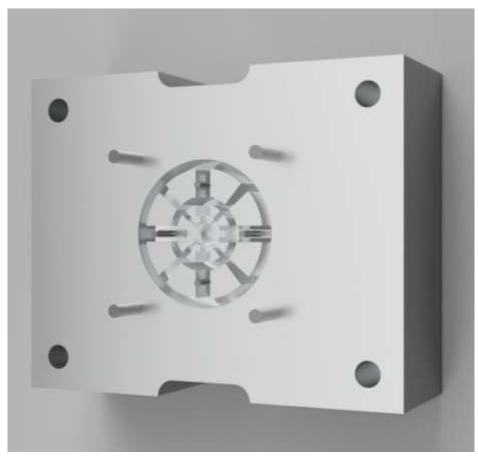
Renderings and Drawings

Rendering of the Wheel Design

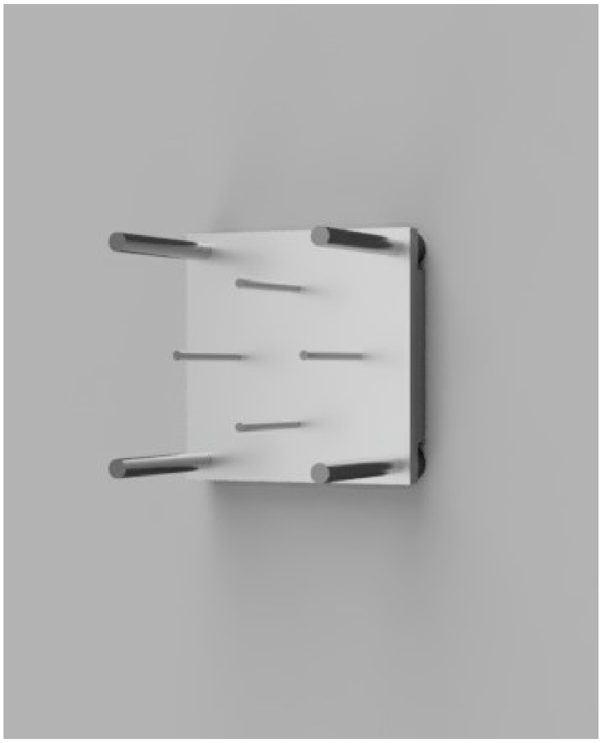
Rendering of Mold Side A

Renderings of Mold Side B





Render of Ejection Plate



Drawings and Step File

https://drive.google.com/drive/folders/12xqH_s1Yrqa9Ae8taBNWmfBabprJo6Nl?usp=share_link

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