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Abstract

Plastic injection molding is an extremely versatile, preferred method of producing plastic parts because it is extremely efficient. In the business of injection molding, it is important to have machines and tools that work properly to get the job done. One such tool is the mold, which forms high quality plastic parts. The main objective of this project is to refurbish the current Frisbee mold to create promotional products for PSU's Department of Engineering Technology. Parts were created with the existing mold to determine what issues needed to be addressed including: excessive flash on the parts/runner, a poor runner/gate design, a poor ejector system, no water for cooling on the mold's B-side, and years of wear and tear. We developed baseline production and cost data when the mold was being tested. Dimensions of the current Frisbee part were also obtained. After finding what could be fixed on the existing mold, we used SolidWorks to create a new thinner Frisbee part design. Additionally, a mold assembly, a mold cavity design, and water channels were added into the B-side of the mold design so that the parts could be cooled. Autodesk MoldFlow Advisor was used to simulate the plastic material's flow in the mold. After the designs were finalized, a new and improved mold was fabricated in cooperation with Vector Tooling, who agreed to donate their services to make the new mold. After the new mold was installed, better quality parts were produced with shorter cycle times, less scrap, and better ejection.

Figure 1. *Pittsburg State University Frisbees*

Introduction

Plastic materials are often designed to fulfill a specific purpose, whether that be long- or short-term applications. Injection molding deals mostly with thermoplastic materials, such as polyethylene and polypropylene, which can be recycled and re-used after they have served their original purpose, making them a widely-used choice in packaging and container products. In general, injection molding is one of the most widely used plastic production methods and is used to manufacture many household consumer products. We can use injection molding to make promotional products, including our promotional Frisbee that helps advertise our university and various programs within the university. Items molded in lab also have the potential to be sold at events or rallies to help raise money and provide funding for our program, which is why having a high-quality Frisbee mold is important.[1]

After years of use and tens of thousands of cycles, the Frisbee injection mold has experienced wear and tear. As we used the mold in our lab, we realized that some of the design features on the mold were not ideal. The Frisbee mold had problems that required the mold to be completely refurbished. These problems included lack of cooling in the B-side of the mold, bad runner and gate design, roughened surfaces in one of the cavities, and wear and tear from processing. These problems caused our process to have a long cycle time and produced parts of poor-quality, including flash and some surface defects. Correcting these problems will result in the highest quality part and fastest cooling time. This more efficient process will greatly reduce scrap and cost per part.[2]

The importance of a new Frisbee injection mold becomes apparent after understanding the cost benefits of the refurbishment. Lowering the Frisbee part weight and cycle time results in a 40% reduction in manufacturing cost. This price reduction will save the department money and allow us to make more Frisbees per hour. If we then market these Frisbees as promotional items to other departments, we can increase our profit margin by reducing our raw material cost. The profit can then be used to benefit other Plastics Engineering Technology students through equipment maintenance, equipment purchase, or travel. When students think about this and some of the other benefits of having a new Frisbee injection mold, they may gain an overall better understanding of why a new Frisbee injection mold is desirable. Exploring the problems with the old mold, finding solutions, and designing a new mold gives future Plastics Engineering Technology students a greater understanding of optimized mold design for injection molding.

Objectives

In order to achieve our goals, our study sought to address the following objectives:

- Evaluate the old mold
- Identify issues that may be improved upon
- Actual cost analysis of old parts and injection molding process
- Redesign mold to produce better Frisbees using SolidWorks
- Proposed cost analysis of new parts and process using potential design and MoldFlow simulation software
  - Thinner part to reduce material costs
  - Add cooling to B-side to reduce cooling/cycle time via inclusion of water channels
  - Revise runner/part design
- Proposed cost analysis of new parts and process using potential design and MoldFlow simulation software
- Enlist the help of an industrial partner to construct the new mold for our Engel injection molder.
- Install the new mold in the injection molder
- Identify potential new material(s) for new part(s)

The overall effect we wanted to achieve was to improve our overall productivity while producing better quality parts with an improved mold design.

Materials and Methods

- Processing tests with old Frisbee mold
  - Resin: Marlex 9006 HDPE
  - Injection Molding Machine: Engel eMotion 310/110 – Electric
  - Evaluate process efficiency and part quality
- MoldFlow Advisor 2019 tests on old Frisbee design
  - Simulated fill time
  - Simulated injection pressure
  - Simulated estimated cycle time
- Determine issues with the old mold
  - Excess Flash on parts/runner
  - Bad runner/gate design
  - Bad ejection system
  - No water for cooling on B-side
  - Wear and tear

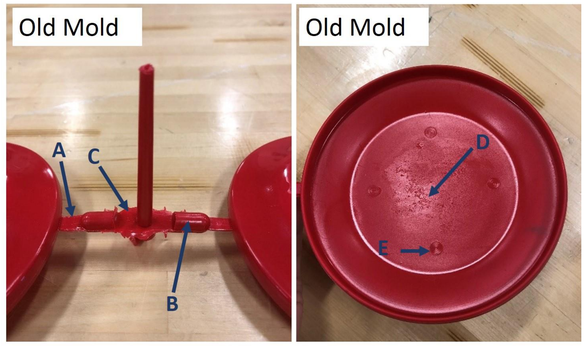

Figure 2. *Issues with Original Part Design.*
A: Gates too long **B:** Runner too thick **C:** Excessive flash
D: Bad surface finish **E:** Ejection pin impressions

- Cost evaluation calculation on old Frisbee mold design to determine cost per part
- Redesign Frisbee part on SolidWorks 2018
  - Create 3D model of Frisbee
  - Mold base model retrieved from DME.net[3]

Materials and Methods (continued)

- Redesign mold cavity inserts on SolidWorks
  - Create 3D models of cavity/core inserts
  - Add new features to fix identified issues

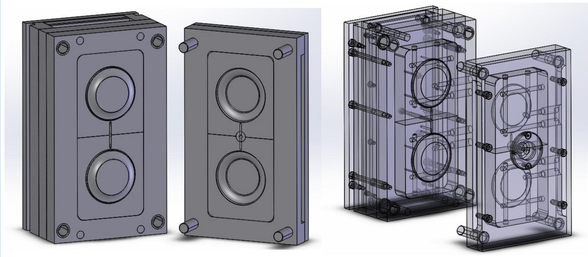

Figure 3. *SolidWorks Frisbee Mold Assembly.*
Left: Solid Assembly Right: Clear Assembly

- MoldFlow Advisor 2019 tests with new Frisbee design
  - Simulated fill time
  - Simulated injection pressure
  - Simulated estimated cycle time

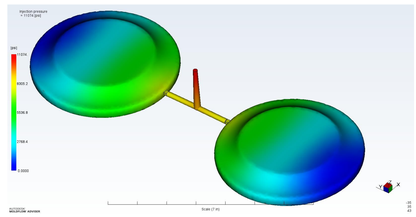

Figure 4. *MoldFlow Injection Pressure for Frisbee Parts.*

- Cost evaluation calculation of simulated results with new Frisbee mold design to determine cost per part
- Send mold to Vector Tooling to be refurbished
- Receive refurbished mold
- Perform processing test runs on refurbished mold
  - Resin used: Marlex 9006 HDPE
  - Injection molding machine used: Krauss Maffei PX 81-100
  - Evaluate process efficiency and part quality

Results

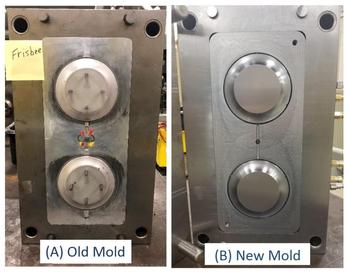

Figure 5. *Physical appearance of old mold (A) vs. new mold (B).*

Table 1. *Comparison of Old and New Frisbee Design Parameters*
(Includes Sprue, Runners, Gates, and Two Cavities)

Parameter	Old Design	New Design	Percent Decrease
Shot Volume (in^3)	4.5855	3.4827	24.05
Total Part Weight (ozs.)	1.922	1.422	26.01
Estimated Cycle Time (secs)	15.26	11.69	23.39
Total Cost per Part	$0.14	$0.10	28.57

Conclusions

Plastic injection molding is a very versatile and preferred method of producing plastic parts due to a high level of efficiency. It is important to have tools and machines that are of top quality and work well. The main objective of this project was to refurbish the current Frisbee mold. To accomplish that goal the following tasks were successfully completed:

- Parts were created with the existing mold to identify issues:
  - Excessive flash on the parts/runner,
  - Poor runner/gate design,
  - Poor ejector system,
  - No water for cooling on the mold's B-side, and
  - Years of wear and tear.
- We developed baseline production and cost data.
- Dimensions of the current Frisbee part were also obtained.
- We used SolidWorks to create a new Frisbee part design.
  - A thinner part was designed.
  - The mold assembly and mold cavity design were revised.
  - Water channels were included into the B-side of the mold so that the parts could be cooled.
- Autodesk MoldFlow Advisor was also used in order to simulate the plastic material's flow in the mold.
- A new and improved mold was fabricated in cooperation with Vector Tooling.
- After the new mold was installed, parts with better quality were produced with shorter cycle times, less scrap, and improved ejection.

Future Work

As an extension of this work we would like to further explore:

- Further testing with different materials and/or material compounding, including:
  - Clear to opaque Frisbees,
  - Rigid to flexible Frisbees,
  - Biodegradable plastics and/or recycling plastic waste reclaimed from the ocean,[4]
  - Addition of colorants,[5]
  - Special effects compounds (metallic, fluorescent, etc.),
  - Functional effects (light reflective, light diffusion, etc.),
  - Shifting effects (Glow-in-the-dark, thermochromatic, etc.), &
  - Material effects (wood, camo, etc.)
- Post-processing designing:
  - In-mold labeling, and
  - Pad printing or screen printing.

Acknowledgements

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