Part Redesign with Minimal Disruption and Additional Cost to Assembly Process

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Abstract

A recent design by Acorn Product Development involved the refresh of an aging product line through the development of a customizable accessory that allowed adaptation to changing consumer tastes. The primary challenge was developing an attachment scheme that did not alter, but still had precise alignment to, the base part. Assembly time and cost were minimized through the development of a single injection molded part using ultrasonic welding at strategic locations to the base part. Reducing the cost of assembly relied heavily on understanding the existing product assembly process to add an additional step with minimal cost and disruption.

Introduction

Acorn Product Development is a product design consultancy that emphasizes the engineering design and analysis aspects of new product design and development. Our company culture is analysis-driven, which means that we strive to understand how a product will function prior to building our first prototype. With this strategy, we enable our clients to achieve revenue-ready products in the most efficient way possible by leveraging design-for-manufacture (DFM) and design-for-assembly (DFA) best-practices. First-order analysis is a critical tool early in our design process – whether structural, thermal, mechanistic, or tolerance analyses. We focus our development expertise primarily in the following four industries: telecom/server, industrial equipment/defense, medical, and consumer products. With offices in Silicon Valley, Boston, Dallas, and Dongguan, China, we support our clients' manufacturing activities both in the US and abroad.

Due to the demanding nature of our client's projects, Acorn is constantly exposed to new challenges that require novel thinking and problem solving. One recent project involved refreshing a high volume, but aging, product line of molded plastic water pitchers. The concept for the update was to create an accessory that improved aesthetics, added some level of protection and allowed a high level of customizability during fabrication. This accessory was referred to as a "sleeve". The client provided Acorn with an industrial design concept of the desired product to kick off the project. This paper highlights the design process and milestone decisions undertaken by Acorn to deliver a product with a robust design that met the sometimes disparate goals of cost, aesthetics and simple manufacturing and assembly.

Early Design

Understanding Restrictions and Risk Areas

The Acorn process of design starts with a thorough analysis of the project parameters. One of the most important aspects that needed to be understood in depth was how the restrictions established by the client might impact the design of the product. This particular water pitcher was a best seller with very high production volumes. This meant that there was a significant amount of capital invested in tooling and backup tooling. Any modification to the tooling was highly discouraged, especially if it impacted other mating parts, due to the significant cost of tooling changes. In addition to this, the volumes of this product were high enough to warrant two separate manufacturers be used to produce the parts. The tools used by each manufacturer were not dimensionally identical, but it was not known at this stage what impact this would have.

It was of equal importance to make an initial assessment of risk areas that would need to be taken into account during the concept generation phase. The first risk area was water trapped between the sleeve and the pitcher. Since the pitcher body is clear and the sleeve could also be clear, any trapped water would be visible to the consumer. Not only is this trapped water visible to the consumer, but water trapped for a long period of time would be at risk for mold growth. This was an unacceptable condition for the product, both from an aesthetics standpoint as well as a health safety standpoint.

The second risk area was the wide range of thermal conditions to which the pitcher would be potentially subjected. From the cold of the refrigerator to the heat of the dish washer (as well as chemical effects from detergents) we had to make sure our concepts took into account any dimensional changes due to thermal expansion or contraction.

Figure 1 - Client ID Model

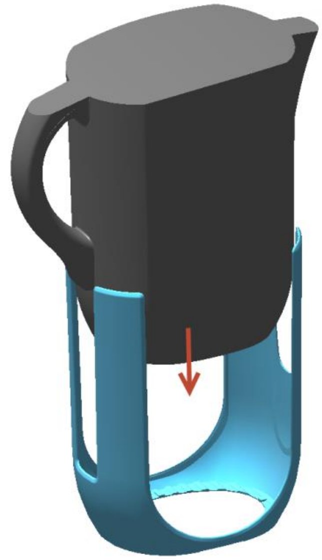

Figure 2 – Installation of pitcher body (top) into sleeve (bottom)

Concept Generation

Once the restrictions and risk areas were understood, the process of generating concepts was started. Acorn utilizes a multi-step process to generate and select concepts that will be able to be developed into functioning prototypes with a high level of confidence.

The first round of brainstorming is typically the most open; all ideas, no matter how exotic, are accepted. Our initial step of assessing restrictions and risks not only allows us to weed out ideas that will definitely not meet our clients' needs, but more importantly, to strategically and intelligently push the boundaries in ways that may inspire the client to new concepts of their own.

Using the Industrial Design ("ID") sample provided by our client and their list of requirements, we brainstormed attachment methods, material options, and manufacturing methods. With each concept developed, we provided a rough sketch illustrating its implementation and supported our inclusion of the concept with an analysis of how this concept meets the needs of the client. The first brainstorm / refinement cycle included only Acorn engineers and the client with the purpose of reducing the number of viable concepts to a manageable number that could be further refined. The second purpose was to discuss the implications of the selected ID and how it would impact the manufacturability as well as the functionality. The results of the first brainstorm that drove the refinement cycle were the following:

1) Selection of injection molding as the manufacturing process for the sleeve
2) Acceptance that sleeve would require spacing from the pitcher in order to allow adequate drainage

The focus of the second cycle of brainstorm and concept refinement was to add more detail to the design of the sleeve and its attachment to the pitcher, focusing on how the sleeve would be attached to the pitcher.

An important aspect of this cycle was the introduction of the two manufacturers currently building this product as another set of eyes to review and comment on the concepts. At this time, the assumption was that the sleeve would be manufactured in two halves to allow the required gap between the sleeve and the pitcher. The inclusion of the suppliers at this step gave us critical insight as to what was feasible within the capabilities of each supplier. It was immediately apparent that each supplier had a preferred direction and level of conservatism. One supplier was very confident with an ultrasonic welding approach of attachment, whereas the other supplier heavily supported an adhesive approach.

By analyzing the feedback from the suppliers and weighing the pros and cons of each method, we determined that the ultrasonic welding would be the best option. The critical factors in this decision were the aesthetics of the weld, the design flexibility of the process, the durability of the attachment and the cost of the assembly. By far the biggest factor that pushed the design towards the ultrasonic welding approach was the determination by the supplier that the sleeve could be molded in a single part and still keep the gaps required for drainage. This reduced the assembly time and handling cost significantly.

Attachment Method							
Concept	Description	Pitcher Tool Simplicity	Sleeve Tool Simplicity	One Piece Assembly Simplicity	Two Piece Assembly Simplicity	COGS	Ease of implementation
C01	Clip	1	-1	0	0	0	1
C02	Clip Metal	1	-1	-1	NA	0	1
C03	Annular Snap Clip	1	-1	0	1	0	1
C04	Clip - Interlock	1	-1	0	1	1	1
L01	Interlock - Double Thick	1	0	1	1	1	1
L02	Interlock - Single	1	0	1	1	1	1
L03	Ultrasonic	1	0	0	0	0	0
L04	Laser	1	0	0	0	0	0
M01	In Mould Labeling	0	1	1	NA	0	-1
M02	Adhesive	1	0	1	1	1	1
B01	Bottom Portion	1	0	NA	NA	NA	NA

Figure 3 - Concept comparison chart

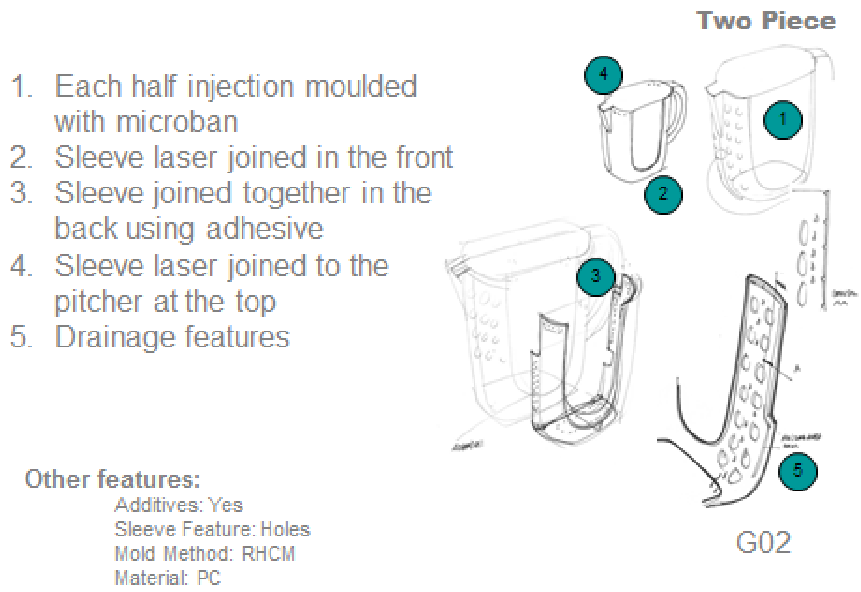

Figure 4 - Example of Acorn Product Development deliverable during the brainstorm and concept development phase of the project

Major Design Decisions

Molding Strategy

Injection molding was selected early in the process as the method by which the sleeve would be constructed. The size of the part as well as the aesthetic requirements dictated certain strategies be used in order to accommodate all the requirements. The part being designed as two halves that were then joined together was selected for two reasons. First, the ID presented by the client had coverage under the handle. The handle was integrally molded with the body of the pitcher, so it was required that the sleeve be two halves to meet under the handle as shown.

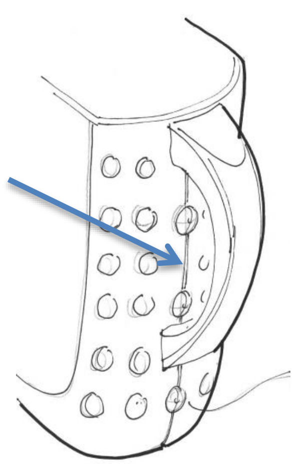

Figure 5 – sample detail showing sleeve joining under the handle of the pitcher

After a short analysis of this design and consultation with both prospective suppliers, it was determined that this design would add significant complexity and limitations to the assembly of the sleeve. For this reason, the joint under the handle was eliminated. This would allow the flexibility of the sleeve to be attached as two separate halves directly to the pitcher, or if desired, it could be joined into a single part before being assembled to the pitcher.

The second reason for the two part design was the drainage requirements. In order for water to not be trapped between the sleeve and the pitcher, there needed to be a gap between these parts. The perimeter of the part would need to be in contact with the pitcher for attachment and spacing reasons. This perimeter contact necessitated an undercut in the part which then drove the assumed pull direction of the tool. By consulting with the supplier before proceeding too far down the path of how to join the two halves, we were able to conclude that the flexibility of the part at the top of the sleeve would allow the part to be "bumped" off of the tool. This would allow the required undercut to maintain water drainage and eliminate the need for two halves of the sleeve or a costly tool with complex actions.

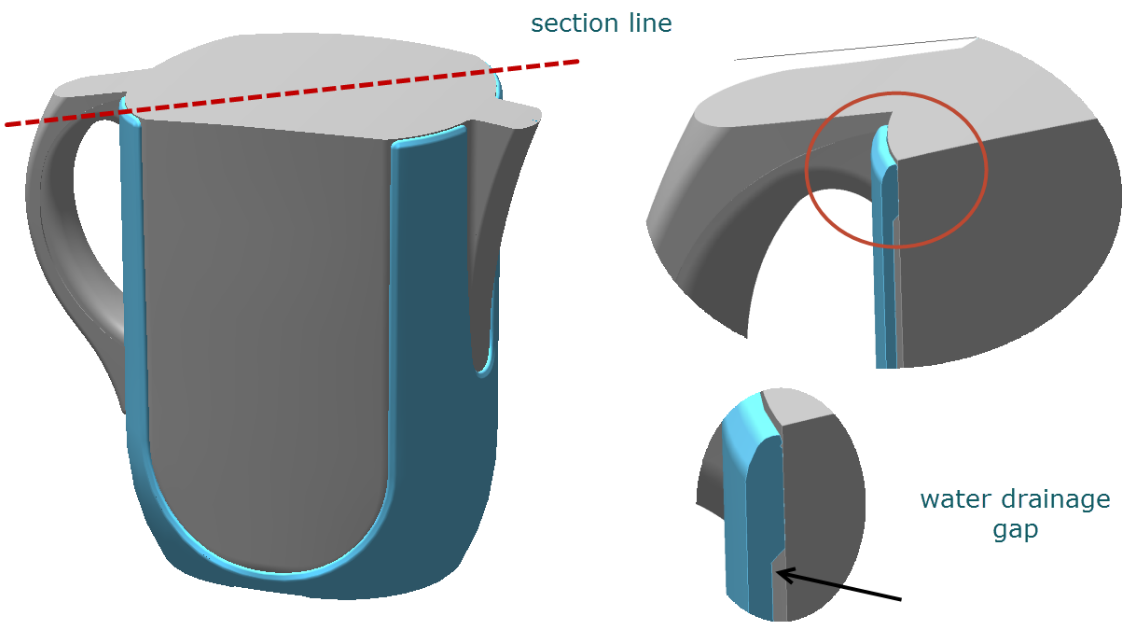

Figure 6 - Water drainage gap and sleeve undercut detail

Selecting Ultrasonic welding as the bonding method

Attachment of the sleeve to the pitcher was a significant challenge because the restrictions of the project dictated that we not change the base pitcher part. After the decision to injection mold the sleeve, we were able to narrow our attachment choices to either adhesive (VHB type foam tape) or plastic welding.

Foam tape has some major advantages. First, there is no tooling required in order to assemble; a person could apply the sleeve by hand, provided some fixturing was present. Also the flexible bond of the tape would help with any thermal expansion issues and drop testing. Lastly, tape gave the opportunity for different materials to be used to make the sleeve. Our further research showed some major drawbacks, however. The pitcher base material was polystyrene, and being a low surface energy plastic, was not ideal for bonding with commonly used adhesives. Another drawback was the foam tape attachment area would have to be fairly large to achieve a suitable bond strength (this data was provided by the supplier).

We ultimately selected a welding process to attach the sleeve. We considered other methods during the design process, laser welding. Despite the major advantage of a watertight seal being possible, the associated costs (both tooling and assembly time) were far too high to be practical for this project.

Ultrasonic welding best met the needs of the project. While there are some drawbacks to ultrasonic welding, they were easily dealt with in the design of the part. For example, welding plastics together requires compatible (often identical) materials to create a maximum strength bond. Using identical materials eliminated the concern of thermal expansion stress if dissimilar material were used. The other major advantages are low to moderate tooling costs, and very fast assembly cycle time. The supplier selected to do the molding and assembly was already a heavy user of ultrasonic welding processes and had extensive experience joining plastics using this method. This greatly reduced the costs associated with creating an assembly line as much of the required equipment was already present.

Leveraging the molding supplier's relationship with a supplier specializing in ultrasonic welding, Acorn was able to apply welding features that were easy to mold as well as easy to weld. This translated to minimized handling of the parts and minimal marking of the parts that would cause cosmetic issues. The supplier took the lead in creating simple molds to test the weld strength and aesthetics of the part to verify it's suitability for the design.

Alignment Features

The supplier selected to mold the plastic parts was integral to creating a well-designed plastic part that would be easy for them to mold and assemble. The big wrinkle with working with this supplier is that they had inherited the tooling from another molder, and due to some problems in the transition; they did not get the 3D CAD of the tooling.

In order to make an accessory that would be guaranteed to fit, we turned to a 3D scanning service to create an accurate base model to design the accessory around. This process was straightforward and only required that we provide a few sample parts for measurement and scanning. The scanning company delivered a 3D model that was based on the scan data, but was editable. While this is a big time saving step, it is important to check that all the surface boundaries are where you expect them. In this project, we found that the overall shape of the 3D model was nearly a perfect match, but there was a surface boundary that was different between the actual part and the CAD which caused a visual mismatch when prototyping parts.

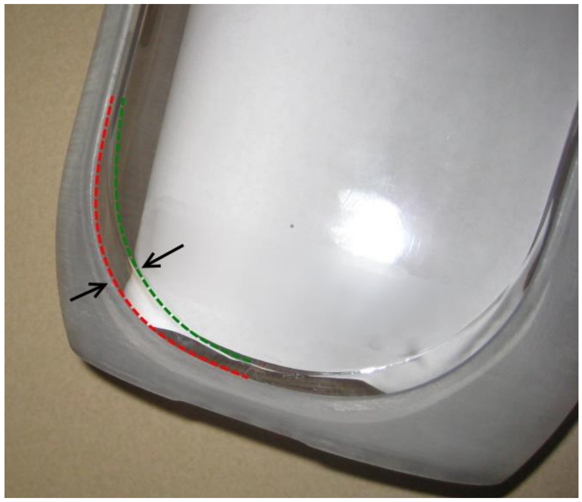

Figure 7 - 3D Scan interpretation error. The result was a sleeve that fit the part, but did not match the borders as shown.

There were three areas where the interface between the sleeve and the pitcher would be scrutinized: around the spout, handle, and the top edge of the pitcher. For each of these areas, we performed a tolerance analysis do determine the required gaps such that the fit would look appropriate despite manufacturing tolerances.

The most important feature was the height of the sleeve relative to the height of the pitcher. Working with the supplier, we learned that there were specific points along the top edge of the pitcher that were measured 100% of the time during the manufacturing process. Using these features, we determined the appropriate gap for the sleeve and the pitcher such that the sleeve would never be taller than the pitcher. Around the spout and pitcher, we used looser tolerances, based on supplier feedback, to perform these tolerance loops. Each of these loops use the base of the pitcher as a datum surface, just as the supplier uses it.

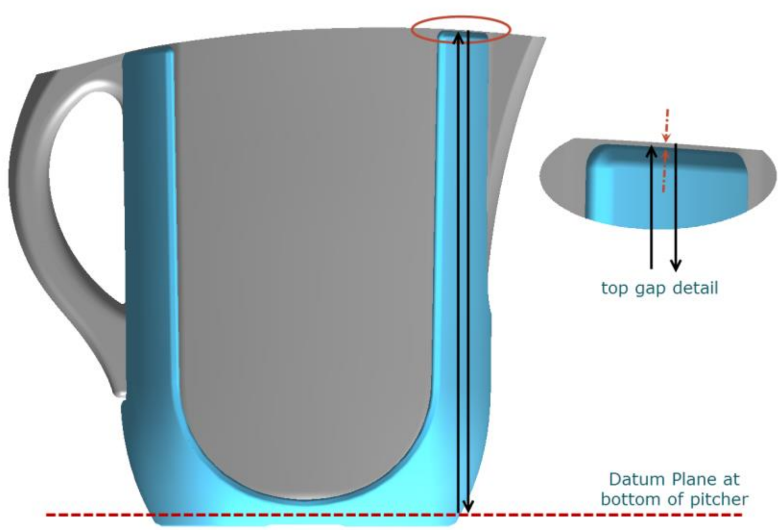

Figure 8 - Tolerance Loop Detail.

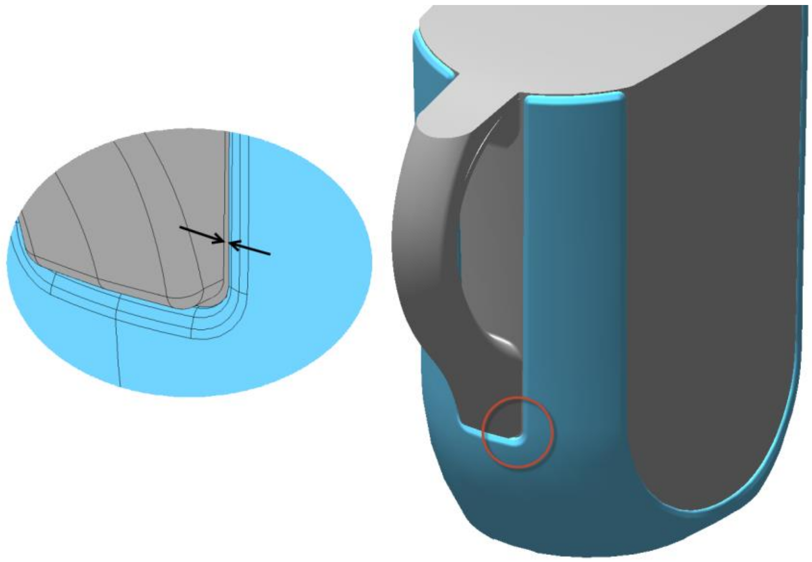

Figure 9 - Detail of gap around the handle.

Conclusion

Molded plastic part design success relies very heavily on the supplier executing the design properly. By including the supplier in the design process early on, the design represents the unique skills and talents of the supplier and results in a part that is cost effective for the supplier to produce from both a material and assembly labor perspective.

This project had many challenging manufacturing restrictions and aesthetic requirements that could have greatly extended the length of the design and prototyping cycle. Its timely completion was in large part due to the close relationship and communication between the client, supplier and design team. Obtaining feedback early-on from the supplier allowed the team to efficiently move the design forward. At each major decision point the manufacturing costs and benefits were analyzed, as well as the impact to the aesthetics, so that all parties could weigh in.

As a result of the frequent collaboration approach, all parties were satisfied with the ease of molding and assembly as well as the cost effectiveness of the design.