Injection Molding: Mold Construction and Part Design

This lecture is based on two plastic parts and associated molds that were built in Solidworks for a mold construction demonstration. These particular parts were chosen, because together, they contain about 90% of the features that one might expect to see in real plastic parts and their associated molds.

The first part is a simplification of a display bezel used on the Silicon Graphics Origin2000 computer.

The second part is a simplification of an air vent used on the sides of the Sun Microsystems SparcStorage Array.

The associated molds built in Solidworks are also greatly simplified from what one might find in real life, but all the essential elements that a product designer might be concerned with are present.

Terminology:

Cavity: This is the half of the mold that forms the outer surfaces of the part. It is characterized by the negative impression of the part carved into the cavity block.

Core: This is the half of the mold that forms the backside of a part. In general, the core material rises up from the core block and almost fills in the back of the cavity. The resulting space between the core and cavity is the wall thickness of the part that will be molded.

Parting line: This is the interface where two parts of the mold, such core and cavity or slide and mold, come together. This term refers both to the interface and the resulting witness line that is molded into the part.

Shutoff: This is a place where two parts of the mold shut against each other and prevent plastic from passing through. Technically speaking, the main parting line interface is a shutoff, but the term is seldom used in this instance. Usually, the term applies to a situation where one part of the mold closes against another to form a slot or hole, or it is sometimes used to refer to the interface where a slide shuts against a core or cavity. Sometimes, the shutoff surfaces are parallel to the direction that the mold opens. When this happens, draft has to be added to avoid grinding the parts of the mold against each other. This type of shutoff is sometimes referred to as a sliding shutoff or a slide-by. An example of this will be seen on the vent mold.

Undercut: An overhanging feature on the part that would prevent it from being removed from the mold.
Silicon Graphics Origin2000 Display Bezel

The Bezel
The bezel has the following features that make it interesting from a tooling design standpoint:
- Curved and stepped parting lines
- A snap formed in the core and cavity
- A hole in middle of the part

Bezel - Cavity Side

Bezel - Core Side

fig. 1

fig. 2
**Overall Bezel Mold**

The mold for the bezel comprises the following elements:

- **Cavity:** This is usually the side of the mold where the main wall thickness of the part is scooped out of the metal.
- **Core:** This is usually the side of the mold where the steel is built up and fills in the backside of the part.
- **Ejectors:** These are pins that are attached to the ejector plate and pass through the core. They are always located on the core side of the mold, since the core is the side that the part shrinks onto.
- **Sprue:** This is the tunnel through which the molten plastic is injected into the mold. The sprue bushing in the fitting on the mold that mates with the hot tip of the injection-molding machine. Like traditional molds, this sprue is located on the cavity side of the mold.
- **Water Lines:** These are holes drilled into the core and cavity through which water of a controlled temperature passes. This allows the molder to vary the temperature of the mold and control the quality of the molded parts.

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**Bezel Mold**

![Diagram of Bezel Mold](image)
Bezel Mold: Core

This view shows the core and ejector side of the mold. The cavity side of the mold has been removed. Due to the shape of this particular part, the core and cavity are somewhat ambiguous. For example, this core does not have the rising mound of steel we would normally expect to see. However, this is considered to be the core by virtue of the fact that the ejectors are located on this side of the mold.

Some items to note:
- The surfaces that are responsible for molding the part are painted orange or red. The surfaces of the mold that contact the cavity side of the mold are painted blue. The center of the mold is mostly blue, because the hole in the center of the part is formed by the contact here between the core and cavity (resulting in a parting line or shutoff).
- The top surfaces of the ejectors follow the contour of the mold. The ejectors are part of the surface that actually molds the part.
- The large pins in the corners of the mold align the core to the cavity.

Bezel Mold - Core and Ejectors
Here we see the same view of the core, except with the bezel (the part being molded) in place.

Items to note:
- No orange surfaces are visible, because the bezel exactly covers them. This is what we would expect, since the orange surfaces are responsible for molding the plastic.
- The main wall thickness of the bezel sits above the surface of the core. This is because the wall thickness is formed in the cavity.
- The bottom and backside of the snap fit into the core side of the mold.
- The sprue and runner system can easily be seen. The sprue plastic is actually formed in the cavity. At the parting line, the sprue makes a right angle turn and becomes a runner that attaches to the part at a constriction known as the gate. Having a hole in the center of this part was advantageous, because it was possible to keep the sprue centered in the mold, without having to attach it directly to a cosmetic surface.
Bezel Mold: Cavity

On the cavity side of the mold, the violet surfaces contact the plastic. The wall thickness of the part can be seen recessed into the mold, forming the shallow cavity. Also, the two surfaces that form the topside of the snap are visible.

This view shows how the part relates to the cavity. Since this is the half where the main wall thickness is formed, we see that the backside of the part is flush with the surrounding steel of the mold. No violet is visible, since the part exactly covers it.

Bezel Mold - Cavity Side, Showing Bezel In Place
Bezel Mold: Parting Lines

These views of the mold show how the two halves come together at the parting line. Because of the curve of the bezel, the parting line is also curved as seen in figure 8. This might have been avoided if the outer perimeter of the bezel had a wall around it. In figure 9, we can see how the features that form the snap lock together. Because the core and cavity have to shut off against each other here, a large amount of draft (at least 5 degrees) is added, to avoid grinding the two halves of the mold together, as it opens and closes.
Bezel Mold: Cross Sections
These cross sections of the mold show how the internal features come together. In figure 10, the runner and gate can be seen at the parting line, to the left of the sprue. In figure 11, it can be seen how the core and cavity together form the snap. Also, note how the holes for the water lines are placed, so that the ejector pins do not pass through them.
Bezel Mold: Mold Opening and Part Ejection

We finally come to the moment where the plastic has been injected into the mold, has cooled off, and the finished part is ready to be ejected. The cavity usually remains stationary and the core-ejector system backs away from it. After the mold has opened a sufficient amount, the ejector plate is advanced with respect to the core, and the ejector pins push the part, along with the sprue and runner, off the core. The part can then be removed from the molding machine by hand or it may drop down and be transported by a conveyor system. Although the illustration depicts the cavity and core opening vertically, in reality, the mold is mounted in the machine horizontally.
Bezel Mold: Sprue, Gate, Runner and Sprue Puller

An item of interest is how the sprue, gate and runner system are handled during the ejection of the part. Since the sprue plastic is rather long, it has a tendency to get stuck in the cavity side of the mold, which is an undesirable situation, since the part would get dragged off the core when the mold is opening. The part should always stay on the core in a predictable fashion, so that the ejectors can push the part straight off without any cocking that might cause damage. To achieve this, a special ejector pin, called a sprue puller is located just under the sprue hole, in the core side of the mold. The pin has an undercutting Z shape cut into it, so that when the mold opens, it is impossible for the sprue to be dragged along with the cavity. This forces the sprue to break off near the top, where the plastic is still hot and molten.

![Diagram of Sprue, Gate and Runner System](image-url)
Sun Microsystems SparcStorage Array Air Vent

The Vent

The air vent has the following features that make it interesting from a tooling design standpoint:

- Sides without draft, requiring the use of slides.
- Angled air vent louvers, formed by core/cavity shutoffs.
- Undercutting hooks that require the use of lifters.
- Injection coming from the core side of the mold.

fig. 14

Vent - Cavity Side

fig. 15

Vent - Core Side

Hooks forming undercuts
**Overall Vent Mold**

This mold is considerably more complicated than the bezel mold. The core, cavity, and ejection system are there, but there are additional features as well:

- The cavity assembly comprises a cavity, side slides and end slides.
- The sprue is located in the core, instead of the cavity. For this reason, there is a hole in the ejector plates, so that the hot tip of the injection-molding machine can pass through and mate with the sprue bushing. This is known as reverse ejection.
- The ejector system consists of normal ejector pins, and specialized ejectors known as lifters. These are not evident in this view of the mold.
**Vent Mold: Cavity and Slide Assembly**

The entire cavity is formed by the cavity, side slides, and end slides. Together, they create the outer shape of the vent. Slides are parts of the mold that can move sideways as the mold is opening, so that there is no need for draft on the sidewalls of the part. The slide motion is activated by angled horn pins in the core, which engage angled holes in the slides.

Surfaces that are responsible for molding the cavity side of the part are painted violet. Surfaces that contact the core side of the mold are painted pink.

![Fig. 17: Vent Mold - Cavity Side and Slides](image-url)
Although the part is not normally seen stuck in the cavity, this view shows how the vent relates to this half of the mold. All of the violet surfaces are hidden by the part, but some pink surfaces are still visible at each louver opening in the vent. These surfaces will be shutting off against similar features in the core side of the mold.
Vent Mold: Slide Details

This detail shows what one of the side slides looks like. The violet surfaces are responsible for molding the sidewall of the vent including the radius that runs along the edge of the “ruffles”. Slides can be used for more complex reasons than the simple need to maintain 0 degree draft walls. For example, if the part required holes or undercutting features on the sidewalls, slides would be the way to achieve those features.

Fig. 19
**Vent Mold: Core and Lifters**

The core side of the mold is responsible for forming the backside of the vent. It includes angled horn pins that engage angled holes in the slides. Also, the core has features known as lifters that form part of the molding surface, but are movable and actually move with the ejector system. These lifter features will be responsible for releasing the undercut hooks on the part, which will be explained at the last section of this lecture. It should be noted that there are some blue areas in the louver areas of the core. These surfaces will be shutting off against mating surfaces in the cavity to form the open slots through which the air flows.

Yellow and orange surfaces are responsible for molding the core side of the part. Blue surfaces contact the cavity and slide surfaces.

![Vent Mold - Core and Lifters](image)

fig. 20
Vent Mold: Louver Shutoffs

A clever feature of this mold is the way a simple core and cavity shutoff can create an angled vent louver that would otherwise require the mold to open up at an unusual angle. To create the slots though which the air flows, the core and cavity shutoff against each other along a line that is almost parallel to the opening and closing direction of the mold. However, this line cannot actually be parallel, or the two halves of the mold will grind against each other when opening and closing. Therefore a minimum 5-degree draft angle is added to the shutoff to prevent this.

Although this design does avoid the need for a slide, it still is somewhat laborious to build, since there are a large number of shutoffs that need to be carefully machined, so that they fit together tightly when the mold is closed.
In figure 22, the core and cavity are shown together, without the part in place, so that the empty space that forms the part can be clearly seen. It is not hard to imagine fitting the part in figure 23 into the empty spaces in figure 22.
Vent Mold: Mold Opening and Part Ejection

Here, the plastic part is being ejected from the mold. As the mold opens, the angled horn pins on the core drive the slides outward, freeing the sidewalls of the part from the cavity. During the ejection phase, the ejector plate pushes both the ejector pins and the lifters to raise the part off of the core. In the next section, we will finally see how the lifters get the part off of the core, even though the hooks create undercuts.
Vent Mold: Lifter Action

Lifters are a clever modification of the normal ejection system that allows undercut features in the core to be ejected from the mold.

A lifter is an ejector pin set into the core at an angle. Attached to the end of the ejector pin is a block of steel that contains the undercutting features.

As the ejector plate moves forward, the lifter moves forward and sideways, simultaneously, due to the angle on the lifter pin. This sideways motion eventually frees the hook on the vent. The lifter maintains contact with the part during the entire ejection phase and actually assists the other ejectors in pushing the part off of the core. For this reason, parts that have a large number of lifters often need little or no regular ejectors.

fig. 25