Injection Mold Design Guidelines

FOURTH IN A SERIES: Nomenclature

By Dr. Paul Engelmann and Bob Dealey
for the Mold Marketing Task Group of the Copper Development Association

Maximizing Performance Using Copper Alloys

Nomenclature for the types of molds is somewhat diverse but usually follows an order describing the type of runner system, mold action and ejection method used. A mold is considered a standard mold when it has a conventional runner system, the part is pulled without any action and the mold only has an opening at the parting line. Occasionally we hear the term two-plate applied to this type of conventional mold. This is not necessarily a correct description and perhaps is only used to differentiate it from a three-plate mold.

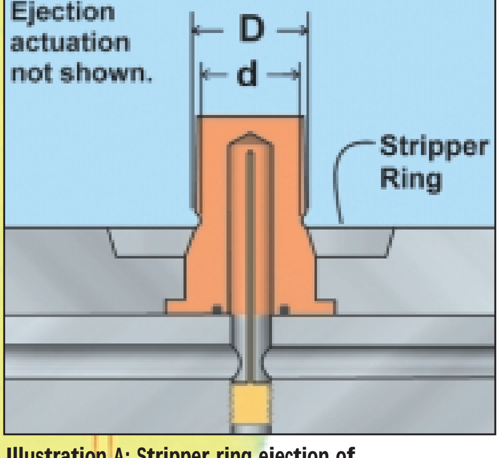

Illustration A: Stripper ring ejection of an undercut.

A three-plate mold has the runner system installed between a separate parting line and the parts are gated with a pin point gate. The advantage is that the cold runner is separated from the parts on mold opening. This type of mold was popular for top gating parts and now frequently a runnerless molding system is used in its place.

Runnerless molding systems (RMS) account for nearly 30% of the molds built today. RMS can be internally or externally heated. If internally heated, the mold has distributor tubes and/or probes with electric heaters placed in the distribution channels to maintain the melt temperature of the plastic as it flows around the tubes toward the gate. Each cavity needs at least one probe to feed plastic for the mold to be a true runnerless molding system. Often hybrid systems are used, especially on small parts where one probe is used to feed a conventional runner system, which then feeds multiple parts. Copper alloy probes have proven to hold more even temperature profiles than steel alloys, especially at the tip end.

Internally heated systems incorporate a manifold with balanced and streamlined passages installed for the plastic to flow from the inlet to the nozzles. Nozzles normally equipped with coil heaters around the periphery and a thermocouple to control the temperature, feed plastic from the manifold to the gate. A very popular divergent flow style incorporates a copper alloy tip, usually made from C17200 or C18000 copper alloy, to aid in maintaining an even temperature profile at the gate entrance to the cavity. The melt flow typically diverges from the center flow passage through orifices allowing the copper alloy tip to extend down to or into the gate orifice. The tip then maintains control of the gate area, freezing the gate during part removal and maintaining the correct temperature to open the gate for the next cycle.

Molds can have many actions, depending on what has to be accomplished, to free undercuts and remove the part from the mold. External threads for example, if not strippable, utilize slide action or expandable cavities to free external features.

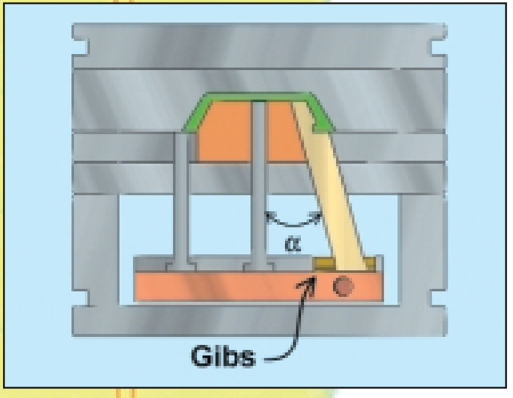

Illustration B: A lifter shown with the mold closed. Lifter angle is exaggerated, should not exceed 5°.

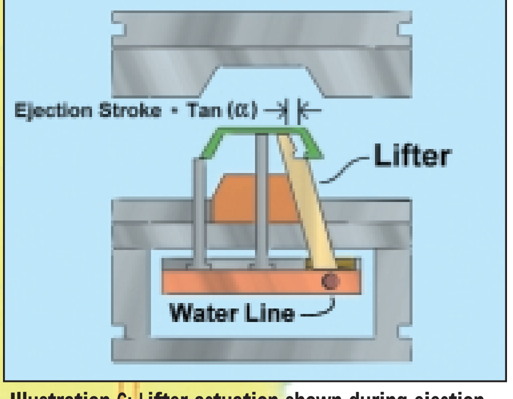

Illustration C: Lifter actuation shown during ejection. Lifter angle is exaggerated, should not exceed 5°.

Internal threads can be formed on collapsible cores or in unscrewing molds. Several methods are used for unscrewing molds, including hydraulic motors, splines, various gearing methods and for large multiple cavity molds, racks and pinions are used.

Other mold actions include lifters, wedges or slifters (a new term), raising members and slides (sometimes referred to as splits, cams and side action). Mold nomenclature then typically describes the type of ejector system used, normally ejector pins, sleeves, stripper rings or plates. Therefore, molds are normally refereed to as "a three plate, slide action sleeve ejected mold", or "runnerless collapsible core, stripper plate mold".

Mold Slides

Undercuts, features on the plastic part that are not in line with normal mold opening, are frequently encountered. When the undercut is small, typically defined as a percentage of the overall part dimension, the best and least expensive option is to determine if the part will flex enough to strip off the cavity or core without the use of a mold action. Freeing the plastic undercut is first dependent upon the plastic material, its flexibility and hardness. The greater the flexibility and more compressive the plastic the greater the undercut can be. The stiffer and more rigid the plastic material, the less the undercut must be. Undercuts are defined as the percentage difference between "d", the amount of the undercut, and "D" the diameter or dimension that the undercut has to snap off (see Illustration A).

Seals are molded from flexible PVC with undercuts greater than .375 inch and a 1.500 diameter, resulting in undercuts of 25%. Modified Closure Manufacturer's Association (CMA) threads are frequently stripped on closure sizes above 24mm in polyethylene and polypropylene, especially in co-polymers. Acme or buttress threads typically will not strip due to the sharp and flat thread profile perpendicular to the direction of draw.

External part features, those normally found on the cavity side of the mold, require that the core be removed prior to attempting to free even the slightest undercut, as the flexing plastic must have a place to compress or expand into if the part is manufactured without moving mold members. When the undercut is too great, the mold cavity can be split or moving cams installed to release the undercut. These plastic part features with details connected to the main wall tend to have the thickest sections. Copper alloys with their ability to cool faster than conventional mold steels have proven to be the best choice of mold materials in these areas. Copper alloys will provide the most even surface temperatures necessary to take the heat away from the molding surfaces. Frequently, the front of the slides are faced or inserted. A copper alloy is inserted on a steel slide carrier and coolant channels are machined through the carrier into the copper alloy insert. With this design, the copper slide face acts as a watered heat sink, drawing heat away from the part.

In all other designs the slide should be designed with the same concept and mold coolant channel as the molds cores and cavities. The coolant channels could include looping flow, baffles or bubbles. A coolant-circulating cascade is available from a number of standard mold component supplies and is ideal for getting coolant into hard to reach areas like those found on a slide. The best practice is to place these coolant lines about two diameters of the cooling channel away from the molding surfaces. This standard works well with the copper alloys, as well as mold steels. However, if you cannot get that close to the mold surface, the more efficient copper alloys, with their higher thermal conductivity, will perform well when the coolant lines are not ideally located.

Mold Lifters

A lifter is a component in the mold that is normally attached to and actuated by the ejector system and moves at an angle to free internal molding detail (see Illustrations B and C). They are typically attached between the ejector retainer and ejector plates with some mechanism allowing the fixed end to slide or pivot to compensate for the movement of the lifter position as it moves at the desired angle. Lifters are frequently used when segmented plastic undercuts (raised mold core detail) is necessary. The lifter has to move out of the mold core at an angle, typically 5° or less, to clear the plastic from the mold lifter detail. This angle is critical for two reasons. First, if the angle were too great the forward motion of the ejector system would put too much pressure against the lifter body. This pressure would create binding of the lifter and lead to excessive wear or premature failure. Should the angle be too shallow, the ejector plate travel would be excessive. Therefore, careful engineering and good judgement has to be made.

Due to their function, lifters are normally long and narrow. Coolant channels are nearly impossible to machine into them. The C17200, C17510 and C18000 copper alloys, normally used in the mold cavity and core, will remove the heat efficiently from the lifter. However, because this is a high wear area and when the mold core is built from one of the alloys already, aluminum bronzes make excellent choices for lifter materials. More information on aluminum bronzes will be included in article eight of this series. To avoid seizing the lifter, one copper alloy riding against another copper alloy is not good engineering practice. One of the components should be plated or coated. The plating or coating should be carefully chosen, as it must provide a low coefficient of friction between the two surfaces. Surface treatments should provide dry lubrication and not be affected by contact with the plastic material and thermal cycling of the mold component due to the molding process.

As the lifters have to move inward from the inside wall of the plastic part to free the undercut, the part must be devoid of any detail that would prohibit or impede lifter movement. Should the part design not allow this required movement the only choice to form this part detail may be with the aid of internal or hidden slides. The problem with internal slides is the amount of room they take to position and move them in a core.

Wedges or Moving Members

Wedges are mold components that have a shape that allows them to fit tight in the molding position but when moved forward free themselves from the pocket to move away from the plastic wall (see Illustrations D and E). They have a guiding system allowing them to move forward and away from internal or external undercuts on the plastic part. The wedges are normally located on the "B" side of the mold and are either pulled with a mechanical attachment from the "A" side of the mold, or pushed by the ejector system or cylinders. While less common, wedges can be installed on the "A" side of the mold.

The wedge must be guided as it moves forward. The two guide systems most frequently encountered are the "T" slot or dovetails. Molds with wedges utilizing dovetails to guide and hold the wedge in position are being called "slifters" in the tooling community. Wedges or slifters have a commonality with lifters. The angle in which they raise must be steep enough to free the undercut within the movement range and yet shallow enough so as not to bind or be exposed to conditions where excessive wear could occur.

By design, these mold members have large areas in contact with the plastic part. Therefore it is necessary to build them with coolant channels and from materials with high thermal conductivity rates. While these wedges and slifters are ideal candidates for the C17200, C17510 and C18000 copper alloys for the plastic forming contact areas, they are not the best choices for the "T" or dovetail guiding systems. Therefore, several options should be considered in their construction. One preferred method is to laminate hardened tool steel to the copper molding face and install the guiding system in the tool steel. Aluminum bronze materials can be laminated to the opposing member of the mold to reduce friction and avoid common tool steels acting as bearing surfaces.

Raising Mold Members

Occasionally plastic parts will have extreme contours. Automotive "A", "B" and "C" pillars, for example, which have geometry where the only way to free the part is to raise it out of the mold and physically or mechanically flex the plastic to remove it from the mold core. These molds are frequently considered raising core molds. This type of arrangement complicates the

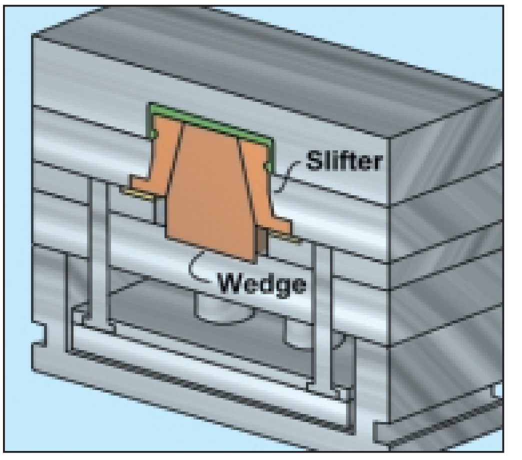

Illustration D: Wedge/"slifter" with the mold closed.

installation of coolant channels due to their contour and shape. Placement of the coolant channels can be far from ideal. Typically a tool steel core member in these applications results in areas where cooling is compromised. Copper alloys have proven time and again that they will, due to their high cooling rates, run cooler and have more evenly distributed surface temperate than a steel counterpart would have. The plastic product almost always has less warp, twist, sink and is more dimensional consistent, due to improved temperature control of this raising mold member.

Other Mold Movements

The injection-molding machine provides one movement when the machine platens separate. The subsequent mold opening provides the mold designer with motion that can be used to mechanically create movement in another plane. Plate movement, commonly referred to as floating of the plates, creates the conditions where the desired mold actions can be incorporated.

One example is the movement of conventional mechanical slides on the "B" side of the mold with an angle pin (see Illustration F). The angle pin(s) is located on the "A" side of the mold and when the parting line separates the pin, due to the angle, moves the slide out. If the same movement is required on the "A" side of the mold the problem of clearing the undercut prior to the main parting line must be overcome. One solution may be to pull the slides with hydraulic or pneumatic cylinders prior to the mold opening. If the slide has plastic forming projected area against it the cavity pressure must be overcome by some locking method.

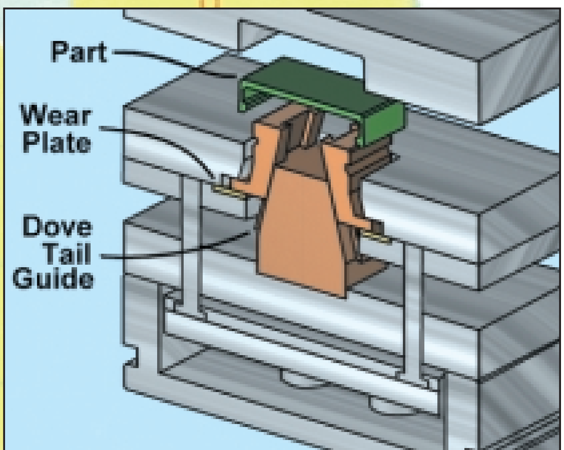

Illustration E: Slifter actuation during ejection, showing the wear plates and dove tail guides.

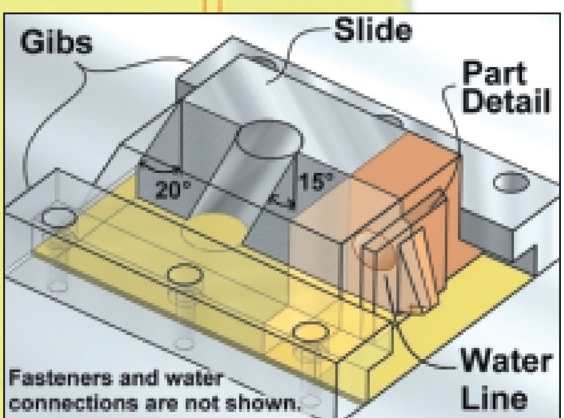

Illustration F: Copper faced slide showing the use of an angle pin. The cooling circuit path and "O" rings between copper and steel are not visible in this view.

Should the area and pressures be small the cylinder may have enough force to prevent movement. If the pressures are great, then a locking cylinder must be used. In any event, the timing of the cylinder retraction and advancement must be tied into the molding machine and measures taken to insure that the slide is in the proper position on mold opening and closing.

To move the "A" half slides mechanically a mold movement has to be established where the "A" plate floats (retaining the plastic part) creating forward movement so that angle pins mounted in the top clamp plate can actuate the slides away from the part and clearing the undercut. Once the part is clear from the slide the plate movement is positively stopped, normally with shoulder or stripper bolts, and the main parting line is allowed to open.

The movement of plates is typically accomplished with a puller mechanism. Frequently external mounted commercially available latch lock devices are mounted on the mold. These mechanisms are solidly attached to the mold member that will be actuating the plate and the opposite end of the device will contact and lock the plate when moving it and release when the desire travel has been reached.

Timing
The expression used to describe the proper sequence of events in mold action is timing. The opening and closing of a standard mold is straight forward, the sequence of events is that the mold closes, plastic is injected, the plastic is cooled, the mold opens, the parts are ejected and the cycle continues. When mold actions, items like slides, lifters, wedges, floating plates, etc. are incorporated, the sequence of events must be pre-determined and the mold designed and built to insure that the proper event happens and that the plate or movement has traveled the correct amount prior to the next sequence starting. Additionally, it is important that the mold actions return in the proper order. Over the years, almost any action or movement has been installed in production molds. We are only limited by our imagination on how to positively insure that the proper mold action will take place at the correct time and then reverse the process to prepare for the next molding cycle.

There is no room for error in sequencing of mold actions. Each operation must be precisely carried out in the proper sequence with the movement required exactly carried out. If any plate or action is left to chance, damage will occur sometime during the molding run. The correct way to design the mold is to positively achieve the desired movement at the right time, while providing a method of determining that the sequence has occurred prior to allowing the mold process to continue to the next step. ■

Acknowledgements
The injection mold design guidelines were written by Dr. Paul Engelmann, Associate Professor, Western Michigan University and Bob Dealey, Dealey's Mold Engineering, with the support of Dr. Dale Peters, for the Mold Marketing Task Group of the Copper Development Association. Kurt Hayden, graduate research assistant, WMU, generated the Illustrations. Research conducted by WMU plastic program students.

Disclaimer
These guidelines are a result of research at WMU and industry experience gained with the use of copper alloys in injection molding. While the information contained is deemed reliable, due to the wide variety of plastics materials, mold designs and possible molding applications available, no warranties are expressed or implied in the application of these guidelines.

Contact Information
Information on copper alloys is available from the Copper Development Association, 1-800-232-3282. Technical clarification of the guidelines can be made by contacting Bob Dealey, Dealey's Mold Engineering at 262-245-5800. Area code 414 until mid September 1999

For more information about the use of copper alloys in tooling, please write in 689 on the reader service card.