Injection Mold Design Guidelines

This Ninth Design Guideline will address applications of copper alloys in molds

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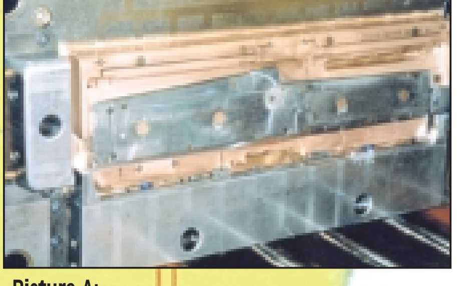
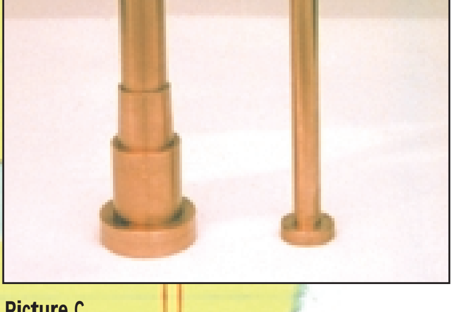
for the Mold Marketing Task Group of the Copper Development Association

Maximizing Performance Using Copper Alloys



Picture A:

Picture B



Picture C

Injection Mold Core Applications
Copper alloys, specifically C 17200, C 17510 and C 18000 continue to enhance performance, reduce cycle time and cost, and improve part quality in injection molding applications. The injection mold core is responsible for removing the majority of the heat from the injected plastic and mold materials with high thermal conductivity consistently outperform those materials with low thermal conductivity.

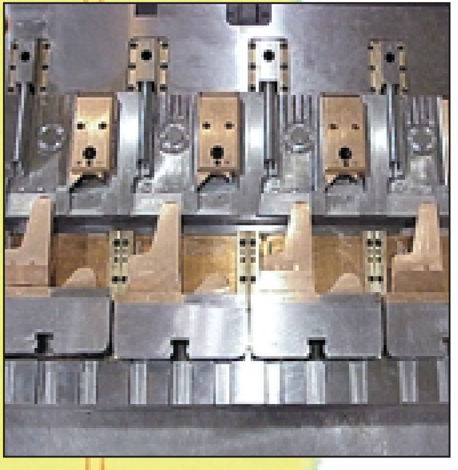
Advantages of mold materials with high thermal conductivity include not only reduction of the cooling phase of the molding process, but also contribute to dimensional control with less tolerance deviation, less part warpage, fewer molded-in stresses and reduced incidence of sink marks.

Copper Alloys for Cycle Reduction
The tremendous thermal conductivity, along with their high density and excellent tensile strength, makes copper alloys an ideal choice for a core material. Molders are reporting between 20 and 50% reductions in the cooling portion of the molding cycle. Kodak, for example in a recent article, reported that in a test mold "copper alloy cores ran 18 deg F cooler than the 420 stainless steel cores." The copper alloys are used in both large and small molds. In large molds, (Picture A), coolant channels are machined into the core similar to ferrous materials. The higher thermal conductivity, up to nine times greater than some tool steels, controls the mold temperature evenly and closer to the temperature of the circulating media.

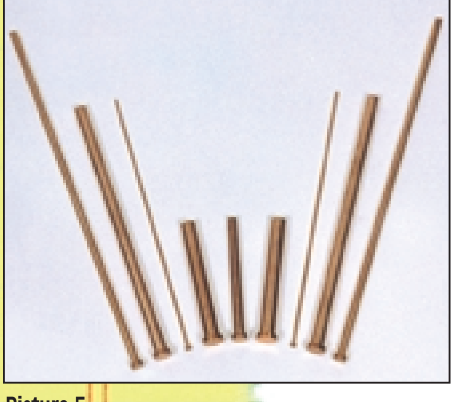
Smaller mold cavity and cores (Picture B), where installing cooling channels in the proper position is a common problem, benefit from the high thermal conductivity of the copper alloys. When coolant cannot be circulated through the small mold core, channels surrounding the core provide an excellent method of extracting the heat from the plastic part, allowing for faster cycles.

High cavitation, high-speed molds benefit from the rapid heat removal characteristics of the copper alloys. These fast cycling molds frequently running in single digit seconds, benefit greatly from the rapid transfer of heat from the molding surface through small diameter cores. Due to the size of many of these mold components coolant channels are impossible to install in the normally recommended proximity to the molding surfaces. The high thermal conductivity of the copper alloy cores transfer heat effectively while maintaining even mold surface temperatures. Multiple small diameter core pins, (Picture C), in contact with chill plates have proven to be an extremely effective method of cooling cores in studies conducted at Western Michigan University. While results from mold-to-mold will vary, the test mold at WMU using the chill plate cooling method, with no coolant circulating in the cores, runs at less than a six second cycle time. This compares to 15 seconds with tool steel cores and a steel chill plate.

Sink Mark Reduction
Sink marks on injection mold parts, resulting from the delayed solidification in heavy part sections after

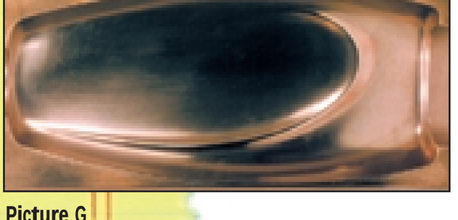


Picture D



Picture E

Picture F



Picture G

the gate has frozen off, can be reduced by application of high thermally conductive copper alloys in strategic positions around the heavy sections. In thick wall and boss sections, coring out sections of plastics with copper alloy core has proven to be an effective method of both reducing the incidence of sink marks and cooling times.

Tighter Tolerances
When product designs call for tight dimensional tolerances with quality levels demanding three or six sigma molding, all molding parameters must be closely held. A constant and uniform mold surface temperature will provide for the greatest opportunity to produce parts with the narrowest tolerance range. The copper alloys, with their great thermal properties coupled with good mold temperature control, provide the right combination for tolerance control in injection molds.

Injection Mold Cavities
In situations where plastic shrinks away from cavity surfaces, cooling conditions are less demanding and the copper alloys are used more in applications where "A" side coring is required. Television backs, for example, have large amounts of detail cored from the cavity side. In these molds, cooling cycle time reductions of 25% have been reported by replacing ferrous inserts with copper alloys. Entire sections of cavities have been inserted prior to final machining and the finished cavity detail has been machined in assembly, reducing mold building, benching and finishing costs.

Injection Mold Slides
Coolant channels are typically difficult to install in slides and moving members of molds. These internal mold actions are usually in locations where proper cooling is paramount for the dimensional stability and/or function of the plastic part. With the sophisticated plastic part design levels demanded from today's injections molds, mold surface temperature control is mandatory in the molding process. (Picture D), shows the use of copper alloys in a four-cavity mold, where due to multiple core draws the part interior is formed entirely by slides. The copper alloys are ideal choices for these slides, as most of the heat from the plastic must be transferred through the alloys to the cooling system.

Core, Sprue Puller and Sucker Pins
Standard off the shelf pins made from C 17200, C 17510 or C 18000 (Picture E) have enjoyed huge success in molds with their ability to transfer heat from the contact area to the base of the pin. A sprue puller pin made from copper alloys rapidly set the puller end of sprue and provides an excellent surface area to hold the sprue on the ejector side of the mold.

Material saver core pins utilized to remove plastic and cool designated areas are the most inexpensive applications of copper alloys while perhaps providing the greatest benefit in reducing the mold cycle time. Three plate molds, where the sucker pins must hold the gate drop firmly to allow the gate to break, cycle faster when the plastic under cut area sets up quicker.

Cladding or Bimetal Inserts
When the properties of both ferrous and copper alloys are required for a particular application, swaging of copper alloys around materials like 420 SS have been used (Picture F). The swaging process insures complete thermal contact without the worries of oxidation forming between the two materials.

Blow Molds
Copper alloys, C 17200, C 17510 and C 18000 have superior corrosion resistance in the presence of polyvinyl chloride and is the material of choice for clear blow molded cavities (Picture G). Again the high thermal conductivity rates of the copper alloys, coupled with their high densities, produce the best molding cycles. Another advantage is the high degree of luster possible with the alloys.

In other applications where neck and tail pinch offs are inserted, the copper alloys are normally specified because of their excellent tensile and compressive strengths. These materials continue to prove superior to aluminum in pinch off applications. Additionally, blow molds that require tight dimensional control and long mold life specify copper alloys for their mold material.

Ejector Sleeves
The aluminum bronze materials, C 62400, C 95400, with their excellent wear characteristics and low

Picture H

coefficient of friction make excellent ejector sleeves (Picture H). As the alloys do not require heat treatment after machining, ejector sleeves maintain roundness better than most ferrous alloys. The secret of holding close tolerances on thin walled ejector sleeves is to machine the internal diameter first and then mount the sleeve on a mandrel and complete the outer diameters. With this method, ejector sleeves with wall thickness as low as .040 inch are routinely built.

Lifters
Internal undercuts requiring lifters (Picture I) can prove to be troublesome. These components typically have narrow cross sections prohibiting the installation of coolant channels. As they are in direct contact with large plastic surface areas massive amount of heat must be removed from the lifter. The aluminum bronze materials C 62400 and C 95400 work well in these applications providing that thin wall sections are avoided. While the thermal conductivity is not as good as the copper alloys recommended for mold cores, it is superior to the ferrous alloys.

Wear Plates
Number one through five mold base materials make poor bearing surfaces for ferrous slides and carriers. Inserting the mold base (Picture J) with one-quarter to one-half inch aluminum bronze plates provide one of the best wear combinations available for injection molds.
Symmetrically designing the wear plates doubles the life, by allowing it to be inverted should damage occur. Additionally, if a burr or chip gets between the wear plate and slide surfaces the wear plate will suffer the damage, rather than an expensive slide.

Slide Gibs
Guiding slides with "L" gibs built from aluminum bronze (Picture K) has become the standard mold of the mold industry. The gibs with their low coefficient of friction against lubricated steel provide an exceptional bearing surface allowing for a close running fit between it and the slide. This close fit insures proper slide to core and/or cavity alignment and guarantees a precision fit.

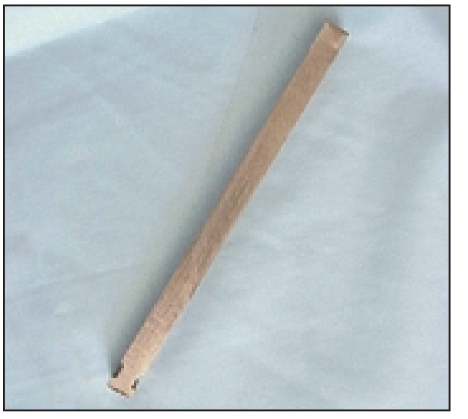
Sprue Bushings
When a large diameter sprue is necessary for maximum injection pressure the molding cycle could be controlled by the thick mass of plastic. Sprue bushings (Picture L), built from high thermal conductive copper alloys, remove heat more efficiently setting the sprue quicker.
Other applications use the copper alloy sprue bushing to purposely increase the orifice diameter reducing pressure loss in the feed system.

Runner blocks
Long and large diameter runner systems used in fully balanced high cavitation molds typically have huge primary runners. These large diameter runners concentrate large amounts of heat in a small area and the molding cycle must be lengthened to enable runner ejection. The C 17200, C 17510 and C 18000 copper alloys, inserted on both the "A" and "B" mold side with coolant circulating in the runner bars, sets the runner faster while reducing the overall molding cycle.

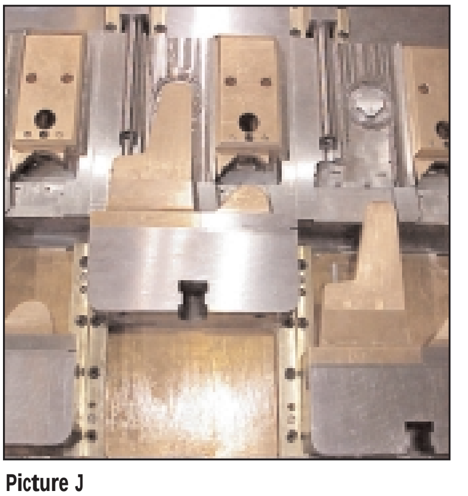
Leader Pin Bushings
The four leader pin bushings in an injection mold are crucial to initial mold alignment and grooved steel leader pins against steel bushings can rapidly deteriorate. Aluminum bronze leader pin bushings (Picture M) running against groveless leader pins have proven to be one of the most ideal and long life combinations in mold applications.

Guided Ejector Bushings
A smooth operating ejector system is mandatory in long running and high-speed injection molds. Utilizing aluminum bronze guided ejector bushings (Picture N) results in minimal wear even in installations where lubrication is hard to apply.

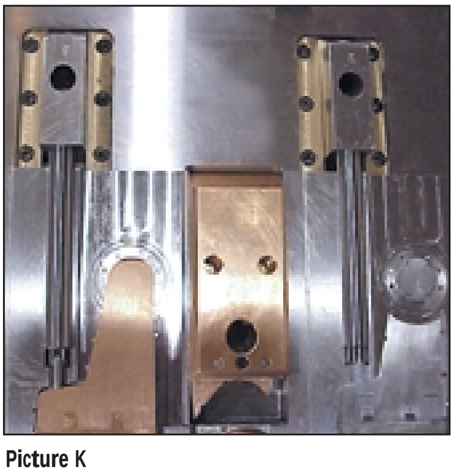
Unscrewing Rack Guide Bearings
Moving mold components, such as unscrewing racks and cam bars which require high speed and close running fits, benefit by aluminum bronze flat bearings inserted



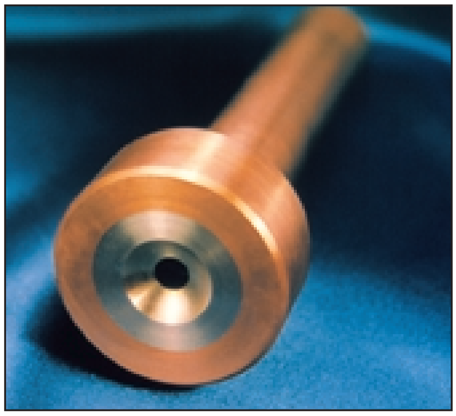
Picture I



Picture J



Picture K



Picture L

Picture M

between the component and mold base. A light coating of high temperature non-migrating lubricant will provide an excellent low friction surface.

Runnerless Molding Systems Components

Runnerless molding systems, frequently referred to as hot runners, probes, drops and bushing divergent tips, benefit from the fast heat transfer provided by copper alloys (Picture O). Materials with high rates of thermal conductivity allow the heat source to be some distance from the tip while maintaining and controlling temperatures within a close range. The importance of maintaining uniform tip temperatures in the gate area on an RMS cannot be emphasized enough. Plating of the probe or bushing will extend component life when molding abrasive materials. ■

Picture N

Picture O

Acknowledgements

The injection mold design guidelines were written by Dr. Paul Engelmann, Associate Professor, Western Michigan University and Bob Dealey, plastic consultant with 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. Special thanks to Whirlpool Corporation, Findlay Ohio, for the use of photographs of their molds for this article. Omega Tool, Menomonee Falls, WI, Progressive Components, Wauconda, IL and Performance Alloys, Menomonee Falls, WI also provided components and photographs for this ninth injection mold design guideline. We appreciate all of their contributions.

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. All coating or plating processes have not been evaluated at WMU.

Contact Information

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

For more information about the use of copper alloys in tooling, please circle 675 on the reader service card.