The main function of an injection mold, beside defining a part’s shape, is to remove heat from the plastic as quickly as possible. The mold should be thought of as a heat transfer device much like the automobile radiator shown above. The faster the mold can transfer heat out of the molten plastic and solidify it, the faster the mold can be run. Reduced cycle time equates to reduced manufacturing cost.

This is where copper alloys outperform other metals used for molds. Copper alloys provide the best combination of high thermal conductivity and hardness for molds used in the plastic industry today. As seen in the table on page 2, hardness and conductivity vary over a range for each alloy system—steel, aluminum or copper. Copper alloys have thermal conductivities 3 to 9 times greater than the commonly used Type 420 stainless steel.

**Uniform Heating**

Another benefit of a high thermal conductivity metal is that it provides uniform heating. Look at a copper frying pan versus a stainless steel pan; the copper frying pan will heat up faster and will have a more uniform temperature profile than the stainless steel.

**Hardness**

Copper is known for its outstanding conductivity, both electrical and thermal. The high-strength, high-conductivity copper alloys discussed here offer the best combinations of thermal conductivity and mechanical properties of any industrial mold material. The table on the next page also shows how the thermal conductivity of the commonly used mold alloys varies with hardness and tensile strength.

The copper alloys offer the best conductivity over a wide range of hardness. Of course, the hardest mold materials are the tool steels.

But mold wear is a surface phenomenon. Surface hardness as it relates to injection molding and other molding processes can, when necessary, be effectively enhanced by the application of surface treatments such as hard chrome, electroleess nickel plating or titanium nitride coating.

**Coefficient of Friction**

Mold coatings used to increase hardness also have a secondary effect of decreasing the coefficient of friction. In addition to the coatings used for increasing hardness, other coatings such as Teflon are used to decrease surface friction.

**Bearing and Wear Applications**

Copper alloys have excellent wear characteristics against steel surfaces. The broad family of aluminum bronze and nickel-aluminum bronze alloys in both wrought and cast
form offer the best combinations of resistance to wear, abrasion, fatigue, deformation and corrosion. Recommended applications include slides, gibbs, wear plates, mold locking devices, sleeve bearings, guide pin bushings, lifter blades, ejector sleeves and pins, and rotating mold components.

Chemical Resistance

Copper is resistant to the acids associated with the molding of vinyl plastics and the chemical attack associated with acetics. Corrosion rates in these hot acid environments associated with plastic molding are low and uniform. Pitting in corrosion tests of these mold materials in aqueous solutions of hydrochloric and hydrochlorous acids has not been observed. However, oxidation can occur if the temperature is above 392 F (200 C)—a temperature above the range used in molding thermoplastics. This tarnishing oxidation can occur as either cuprous oxide or black cupric oxide, both of which can be removed in hydrochloric acid.

Metal Cost

Copper alloys are often the most cost-effective mold materials when a total product cost analysis is made. Copper alloys can be more costly than other mold metals, but copper alloy molds often achieve the lowest total manufacturing cost. This is because the metal cost generally accounts for less than 15% of the finished mold cost, and also because the copper alloy mold is uniquely effective in decreasing molding cycle times.

The graph on the next page makes this point schematically. Cumulative Total Part Cost (tooling cost plus molding costs) is plotted on the vertical axis versus Thousands of Parts produced. Note the higher initial cost of the copper tool is paid for early in the production life, and from then on, the reduced production costs associated with the copper tooling result in an ever increasing margin, compared to the lower conductivity and lower productivity of a hardened steel mold.

In Use Today

Polyesters and copolyesters are currently used in a variety of molding applications. These polymers require good mold cooling, as they will “stick” to warm steel molds at temperatures above about 90 F (32 C). This sticking problem can be overcome if the molds are properly designed. Proper design usually means excellent cooling in the mold itself.

Copper alloy molds and components have proven of particular value in this regard when molding the heat-sensitive polyester resins. For many years, engineers and mold designers have specified copper alloys in difficult to cool areas, such as core pins, blades, slides, inserts and sprue bushings.

Comparison of Mold Alloy Properties

<table>
<thead>
<tr>
<th>ALLOY</th>
<th>UNS NO.</th>
<th>DESCRIPTION</th>
<th>THERMAL CONDUCTIVITY (Btu/ft·hr·°F) at 68 F (W/m·K) at 293 K</th>
<th>ROCKWELL HARDNESS*</th>
<th>TENSILE STRENGTH* (ksi) (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEEL</td>
<td>S42000</td>
<td>Type 420 Stainless Steel</td>
<td>14.4</td>
<td>C 27-52</td>
<td>125-250</td>
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<td></td>
<td></td>
<td></td>
<td>24.9</td>
<td></td>
<td>863-1725</td>
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<tr>
<td></td>
<td>T20813</td>
<td>H-13 Tool Steel</td>
<td>14.4</td>
<td>C 38-54</td>
<td>206</td>
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<td></td>
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<td>24.9</td>
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<td>1421</td>
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<td></td>
<td>T51620</td>
<td>P-20 Tool Steel</td>
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<td>C 28-50</td>
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<td></td>
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<td>38.1</td>
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<tr>
<td>ALUMINUM</td>
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<td>Type 6061 T6</td>
<td>96.5</td>
<td>B 60</td>
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<td>166.9</td>
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<td></td>
<td>A97075</td>
<td>Type 7075 T6</td>
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<td>67</td>
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<td></td>
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<td>COPPER</td>
<td>C62400</td>
<td>Aluminum Bronze</td>
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<tr>
<td></td>
<td>C17200</td>
<td>BeCu - High Hardness</td>
<td>62.3</td>
<td>C 41</td>
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<td></td>
<td>C17200</td>
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<td>190</td>
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<tr>
<td></td>
<td>C17510</td>
<td>BeCu - High Conductivity</td>
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<td></td>
<td>C18200/18400</td>
<td>Cr - Hardened Copper</td>
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<td>B 96</td>
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<td></td>
<td>C64700</td>
<td>NiSi - Hardened Copper</td>
<td>233.6</td>
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<tr>
<td></td>
<td>C18000</td>
<td>NiSiCr - Hardened Copper</td>
<td>233.6</td>
<td></td>
<td>352-483</td>
</tr>
</tbody>
</table>

* For 1-inch rod; properties vary with product form and size.

Note: The copper alloys are also available in cast versions with similar properties.
APPLICATIONS OF COPPER ALLOY TOOL COMPONENTS

Sprue Bushing
Copper alloy sprue bushings are used to achieve better temperature control of the contained melt inside. For those applications where the melt is prematurely freezing-off inside the sprue bushing, a copper alloy sprue bushing increases the rate at which heat can be transferred to the melt and keeps it molten.

For those applications where the sprue and runner is thicker than the part and is limiting the cycle time, a copper alloy sprue bushing increases the rate at which heat can be transferred from the melt and solidifies the sprue faster. This produces a faster molding cycle which equates to reduced manufacturing cost.

Hot Runner Manifold Heater
For more demanding applications, where a hot runner manifold is needed, a copper alloy heater module provides faster start-up times because of faster heat transfer to the melt. It will also provide better melt temperature control because of faster heat transfer response.

Engraving
Engraving can be done with copper alloys. The same care has to be taken to provide draft angles and relief as with other mold materials.

Molds for Injection- and Blow-Molding
Copper alloy molds provide faster cycle times for both injection- and blow-molded parts because of their superior heat transfer characteristics. Faster cycle times reflect better equipment utilization, forestalling the need to purchase additional equipment.

Graph showing how total manufacturing costs can be reduced by switching to copper alloy molds.
Cores
In most thermoplastic processing, the plastic shrinks onto the core and may separate from the cavity wall. When that happens, the majority of the cooling of the plastic is from the core. Molders have found that cycle times can be dramatically cut by inserting copper alloy cores in their molds. Copper alloy cores can be of any geometry—from simple cores to the most complex.

Products
A wide range of resins and plastic products are molded using copper alloy tooling. These products range from high mechanical-property and tight dimensional tolerance requirements to those with lower requirements.

THE FUTURE
The future applications for copper alloys in the plastic industry are bounded only by your imagination and creativity in applying sound engineering to this proven group of materials. For more information contact:

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