Molding plastics with molybdenum

Molybdenum-alloyed mold steels are a key component of plastic injection-molding machines. They must be easy to machine into complex geometries that mirror the finished molding, resist deformation and wear under the stress and abrasion of the process, and be able to maintain a high surface polish for long production runs. Molybdenum is a vital alloying element in meeting these requirements.

Plastic objects are ubiquitous today. They can be small and simple, like disposable bottle caps, or large and highly engineered, like multi-component aircraft parts. They are found in a multitude of sizes, forms, colors, and applications. Of the many molding processes available for their manufacture, the most widely used and versatile is injection-molding. As its name implies, this process injects molten plastic into a mold, usually made of steel. Molybdenum-alloyed steels are the mold material of choice because of their strength and durability at elevated temperatures. They represent an important market for molybdenum.

Injection-molded parts range from shoe heels serving massive markets to limited numbers of precision items for medical devices. © iStockphoto/TPopova

Injection-molded products

Two examples of injection-molded products serve to demonstrate the flexibility and range of the process. The first is high-pressure gas tanks. These are constructed from an inner blow-molded plastic cylinder, wrapped in glass or carbon filament, then covered by an injection-molded plastic shell. These tanks are about 70% lighter than steel tanks with a similar pressure rating, making them ideal for mobile applications such as commercial and private vehicles operating on natural gas or hydrogen. Both traditional combustion engines and fuel cells rely on them for their fuel supply. Even the market for lower-pressure liquefied petroleum gas (LPG) canisters is seeing an increase in the use of composite plastic containers because of their light weight and durability.

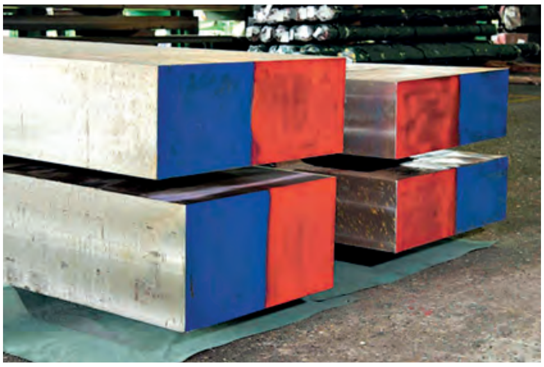
A second seemingly mundane, but potentially game-changing product, is a recyclable, BPA-free, transparent, multilayer, injection-molded plastic can that may well replace the traditional metal food can. Its manufacturer calls it the “Klear Can”. A major machine manufacturer recently announced the sale of its first Klear Can production system. The design provides the same benefits as airtight metal cans, but in a see-through plastic container that allows consumers to clearly see a can’s contents. The product can store shelf-stable foods for up to five years.

The plastic (resin)

Molders can choose from hundreds of different thermoplastic resins, plastics that soften upon heating and become hard after cooling, offering a myriad of properties to the product designer and manufacturer. Common resins include polyvinyl chloride (PVC), polyamides (Nylon), acrylonitrile butadiene styrene (ABS) and polyethylene. Each resin offers a unique set of properties that must be considered with respect to both the resin’s performance in the injection-molding machine, e.g. maximum molding temperature, fluidity, corrosivity, and the finished product’s performance in its application, e.g. colorability, strength, toughness and surface quality.

›

Plastic molding begins with resin pellets and ends with a myriad of simple to complex parts. © iStockphoto/XXLPhoto



The mold is machined out of a block of mold steel produced by a specialty steel producer. © Alloy Tool Steel, Inc.

Injection-molding machines

Injection-molding machines have four major components – motor, injection unit, split injection mold, and clamping unit. Machine size varies greatly depending on the size of the finished product, and is rated according to mold-clamping force. Small units may have only 2 MT of clamping force while very large machines may be rated over 10,000 MT. The basic elements of all machines are similar and quite simple, but they can become very complex when the marketplace requires high quality and high production rates.

Injection-molding machines come in a range of sizes and production speeds, but all have the basic features of a resin delivery and molding system. © iStockphoto/Baloncici

Mold design

The split-injection mold, consisting of a frame and plates, is common to all machines. These highly sophisticated molds require separate channels for introducing the resin and evacuating air, for cooling with either water or oil, and for guiding ejector pins that remove the part from the mold. High-production molds contain cavities for dozens of parts, which adds to the mold's complexity.

Modern mold design employs computer-aided design (CAD) to supplement the mold maker's art. The computer allows the mold maker to design the cooling, venting, and ejection systems while considering shrinkage, warpage, forces, and component deflections. Computer numerically controlled (CNC) machines use the CAD program output to control mold machining, allowing precise dimensional control of finished parts. Electro-discharge machining (EDM) is frequently used when a single mold must produce many small parts. The advantage of EDM is that it can machine a mold after final heat treatment. The mold cavity is often polished after machining to achieve good surface quality on the finished part.

Mold materials

The design engineer must consider various factors when selecting a material. Foremost is the mold's required life. Other factors include the temperature needed to process the resin and the surface finish required in the end product. Various steels, copper and aluminum alloys, rubber, and even epoxy are used as mold materials; the last two typically finding use for short runs or prototype production. Steel is by far the most common mold material, and is favored for its durability and high-quality products.

The mold material must be machinable and capable of producing the required surface finish. It must have strength to withstand clamping forces and wear resistance for long production runs. Steel alloys must be hardenable in relatively thick sections while delivering good toughness and dimensional stability during heat treatment. These requirements make molybdenum-containing tool steels the perfect choice.

Two of the most widely used steel grades, AISI P20 (UNS T51620) and AISI H13 (UNS T20813), have nominal molybdenum contents of 0.42% Mo and 1.3% Mo, respectively. These two alloys have spawned a large number of compositional variants to customize them for specific applications; most retain Mo in their composition. One major mold steel supplier offers fourteen variants, with molybdenum contents up to 3.6%.

The most important material property, particularly for high-end parts, may be good polishability that assures a blemish-free surface. Blemishes are almost always caused by non-metallic inclusions that create discontinuities on the surface of the final part, often resulting in rejection. Special melting techniques such as vacuum arc remelting (VAR) and electroslag remelting (ESR) can minimize inclusions, and are typically offered at a premium price.

Outlook for plastics and the molybdenum industry

The global plastics industry is huge and growing. In the United States, it is the third largest manufacturing industry. The injection-molding segment alone is expected to grow at a CAGR of 4.2% through 2022, driven in part by exciting new products such as gas storage and transport tanks and the Klear Can highlighted here. The ever-increasing demand for larger components having more sophisticated design and better performance continually requires more injection-molding equipment and tooling. Molybdenum, as it has throughout its history, will help to provide the right steel for these new products because it brings strength, stability, durability, and high-surface quality to the steels used in injection-molding.
(Curtis Kovach)