

mold-release agents and coatings

Improvements in the durability of mold-release agents are allowing manufacturers to produce more parts with reduced cycle times and lower rejection rates.

In the processing of metal, rubber and plastic, molds are employed to shape the specific material being used into a specific part. The operating conditions usually require precise heat and cure times, and the finished parts must meet a specific surface finish. Without the use of a mold-release agent or a mold coating, these applications could not be conducted.

Poor part quality can result if the mold-release agent or coating used is not formulated properly or recommended for the correct application. This article reviews the key types of mold-release agents and coatings, their functions and technology trends. Interviews were held with representatives of mold-release manufacturers and mold-coating producers to obtain their perspective.

FUNCTION AND TYPES

Mold-release agents provide a coating or boundary to facilitate the removal of the part from the mold surface. Mark Finn, vice president of sales and marketing for the McLube Division of McGee Industries, in Aston, Pa., further explains, "Their main function is to release a part from the mold without damage. They act as a low-energy barrier between the mold and the part being molded. A coating is formed on the mold surface with a low surface tension that must not be transferred to the molded part. There should also be no contamination of the mold material."

In essence, mold-release agents provide many of the same characteristics as other lubricants, including reducing friction and wear by acting as a boundary layer between the part and mold surfaces.

Miguel Psillakis, vice president of marketing and technology for Chem-Trend LP, in Howell, Mich., says, "Mold-release agents impact the process characteristics such as the flow rate of the material into the mold cavity, mold cycle time and the ease of release. Proper selection of the release agent affects the finish characteristics of the released part such as gloss level, accurate texture reproduction and post-molding operation. Mold-release agents also influence the mold service life between maintenance cycles and the overall productivity of the process."

STLE-member Stacey Lorenz, R&D manager for J&S Chemical Corp., in Canton, Ga., agrees that mold-release agents have a major impact on process parameters. He says, "Temperature control is a very important function of a mold-

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Figure 1 | The main way mold-release agents are applied to the mold is through the use of a spray gun. The nozzle is adjusted to ensure proper atomization and good film formation. [Courtesy of Chem-Trend LP]

release agent. Molds do have hot oil and cooling lines (with water) that control the temperature, yet the release agent imparts cooling and enables a certain operational temperature to be maintained during the process. Maintenance of the integrity of the casting (including minimizing defects) and protection of the mold from buildup of the material being processed are two other key functions of the release agent."

The three main types used to carry out these functions are sacrificial, semipermanent and internal mold-release agents. Psillakis says, "The sacrificial type is applied after each molding cycle because it is readily depleted. A semipermanent mold-release agent chemically reacts with the mold surface to generate a chemical and physical release barrier. This enables multiple molding cycles to occur before additional release agents must be reapplied."

"Internal mold-release agents are formulated into the material being molded," Psillakis adds. "They are generally incompatible with that material which enables them to exude to the surface of the part, promoting its release from the mold. The exuding mechanism of the internal mold-release agent can be accelerated by heat."

In a similar fashion to lubricants, mold-release agents can be formulated from a number of different components. Finn says, "External sacrificial agents can be prepared with powders, soaps, waxes and oils (silicon- and polyglycol-based). Semipermanent coatings are formulated with fluorochemical

polymer resins such as polytetrafluoroethylene (PTFE) and functional silicone polymers. Solid powders and fatty acids are key components used in internal-release agents."

Lorenz indicates that one key factor that a mold-release agent must overcome is the Leidenfrost effect. He explains, "Water in contact with a mold hotter than its boiling point can form a steam barrier layer that prevents the release agent from wetting the surface. This phenomenon is known as the Leidenfrost effect and can delay the release agent from coating the surface. Use of specific wetting agents is required to overcome this problem."

The Leidenfrost effect typically occurs at temperatures above 200 C, according to Lorenz. He indicates that mold temperatures typically range from 150 C to 425 C.

Each type of mold-release agent has advantages and disadvantages. Finn says, "Sacrificial formulations exhibit inferior heat stability and do not adhere that well to the mold surface. For this reason, they are applied more frequently and do not provide multiple releases."

"Semipermanent release agents are more thermally stable and display low coefficient of friction values due to the use of fluorocarbon and silicone polymers," Finn says. "They exhibit excellent lubric-

ity, good antistick properties and high-temperature applications up to 590 C. The result is that semipermanent release agents do not transfer to the mold surface and are effective

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for multiple release cycles due to their durability. Internal-release agents tend to contaminate mold surfaces and change the properties of the release agent. They are used mostly in the plastics industry."

Psillakis points out that release agents also can be organized by the type of carrier. In a similar fashion to other lubricants, they can be prepared in solvent, water or as solids. He says, "Solvent-based formulations are easy to apply, but application could be restricted due to VOC and environmental concerns. Water-based release agents are emulsions. The use of water improves the environmental friendliness but is more prone to bioactivity concerns, and proper biocides are required. Solid-release agents are offered in powder form and are usually applied through the use of an electrostatic spray gun. But a dust hazard can be present if the application is not done properly, and special application equipment (often times electrostatic spray guns) may also require additional modifications to the molding equipment. This factor could preclude wide use of powders."

SELECTION AND APPLICATION

A number of factors need to be considered before recommending a suitable mold-release agent for a particular application.¹ Lorenz says, "Key issues include the temperature of the mold, type of part (for metals the alloy), volume or casting size and complexity of the part. Included in the latter are the thickness, geometry and shape of the part."

Psillakis also considers process conditions such as the line speed/cycle time, temperature and process variable fluctuations to be important. He adds, "Customer expectations are important, which means that productivity and performance criteria such as the number of good releases or good parts demolded per time must be determined. Part finish and the frequency of mold cleaning also need to be considered."

Finn believes the origin for how to select a mold-release agent lies with the lubricant industry. He says, "The lubricity characteristics determine how effective the part is moved into and out of the mold. Static and dynamic factors must be considered when selecting a mold-release agent with a particular lubricity. The former refers to the need to get the molded part out after it is prepared while the latter involves ensuring that an even flow of material moves across the mold."

Finn points out that having an even flow minimizes the formation of voids on the mold surface. A second way to

look at lubricity, according to Finn, is to evaluate the antistick nature of the mold-release agent. As the term suggests, antistick performance refers to the ability of the release agent to remove the part from the mold.

Mold-release agents are applied to the mold by several techniques. Psillakis says, "Application is a key aspect to be observed and may significantly influence the performance of the release agent. In most cases, a spray gun (manual or robotic) is utilized to apply release agents." An example showing the use of the spray gun is shown in Figure 1.

The gun has a nozzle that is adjusted to ensure proper atomization and good film formation. Psillakis indicates that aerosols or wiping systems also can be used.

Lorenz works mainly with water-based release agents, so dilution is important. He says, "We can dilute release agents between 20:1 and 300:1 with water using a proportioning system. Spraying of the release agent is done in an automated fashion robotically or by using fixed heads and in a manual process by a hand wand." In a number of cases, Lorenz reveals that multiple nozzles may be required to apply the release agent.

Finn feels that the choice of a solvent- or water-based release agent plays a major role in the application. He says, "With a release agent needing to wet and then dry on a mold surface, the temperature of the system is important. Solvent-based release agents will wet the surface and then readily dry so that the user will be ready to initiate the application process in a matter of minutes. Water-based products need to dry, which will delay making the part but are safer to use."

Finn also points out that care must be taken in using solvent-based products because if the temperature is too hot, the release agent will flash off quickly and not properly wet the surface. For

this reason and for safety considerations, the mold-release industry has moved actively toward water-based products, particularly over the last 10 years.

Psillakis believes the chemical interaction between the molded part and the release agent dictates performance. He says, "The release agent should not be chemically compatible with the material being molded. It needs to offer a good chemical and physical barrier to prevent the molded compound from chemically interacting with the mold. This is analogous to not having a non-polar solute in contact with a non-polar solvent as like dissolves like."

The use of molds made from different materials and the

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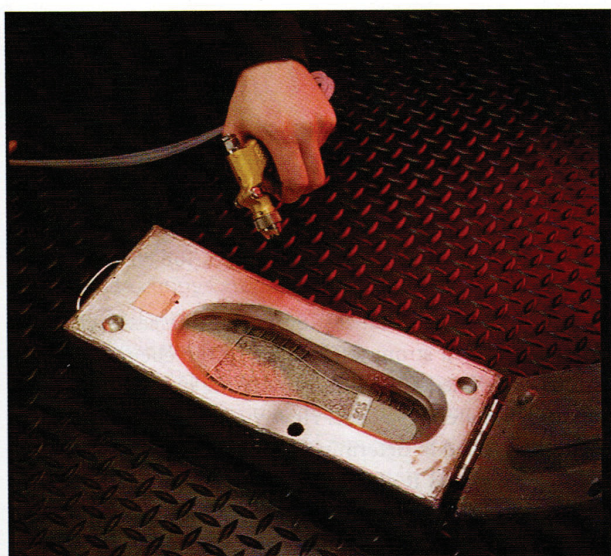


Figure 2 | A mold-release agent is used in the processing of rubber soles. [Courtesy of Chem-Trend LP]

different compositions of metal alloys, plastics (thermoplastics and thermosets) and elastomers used to generate parts makes the recommendation of a specific release agent that can meet the specific molding processes and conditions very important. One such application is in the preparation of rubber soles for shoes, as shown in Figure 2.

TRENDS

Besides the move to water-based release agents, Finn points out that durability is becoming a very important parameter. He says, "In the past, release agents were applied before each cycle in which the part is made. But now more durable coatings are available that can last for longer periods. This enables users to hold off spraying release agents from five up to 30 cycles."

Improved durability is possible because the release industry moved to using semipermanent products based on functional silicone and PTFE polymers. Finn adds, "We have seen part-rejection rates drop from 30% to 10% when the release agent has been switched from a conventional sacrificial type to a semipermanent-, silicone- or PTFE-based product. The application in this particular case is a rubber motor mount that sits on the frame of an automobile."

Psillakis feels that the move toward parts made from innovatively engineered materials presents an ongoing challenge to release agent suppliers. He says, "Parts made with these materials provide better performance under more demanding conditions. For example, newly developed fluoropolymer compounds that can be molded at high production rates and minimum scrap levels are being used to make components in automobile engines. But these polymers are more difficult to mold and release."

Development of complex molds, an increase in high integrity (semisolid and squeeze) castings and reduction in cy-

cle times in high-pressure aluminum die casting has created the need for release agents with improved antisolder properties, better lubricity and release performance, according to Psillakis.

Psillakis also sees the movement from solvent-based to water-based release agents in many industry segments. He says, "Water-based technology has been developed to provide uniform gloss level and appearance for polyurethane parts such as automotive steering wheels and dashboards. A similar approach was done in molding of conventional composite and advanced composite parts for use in various industries, including aerospace, boats and the recreational vehicle industry."

Buildup of residue on the mold and overspray areas can have a negative effect on performance. Lorenz says, "Too much buildup on the mold over time will obstruct or plug vent passages. Vent passages allow gas or vapor to be exhausted or evacuated during the casting process. Porosity in the casting can occur if this gas or vapor is not properly removed. Buildup of residue can also be formed on surfaces not involved in the application due to overspray mist."

"This overspray buildup can cause increased maintenance and housekeeping issues," he adds. "Much of the residues formed have been due to the industry's use of wax-based products. In response, release agent suppliers have moved toward wax-free, water-based emulsions that generate minimal buildup."

POTENTIAL PROBLEMS

All three representatives interviewed indicate that mold-release agents should not cause problems in manufacturing when used properly. Psillakis says, "The wrong selection of a release agent and/or the release agent application methodology for a molding process can lead to a residual buildup on the molded part and/or on the mold surface. This buildup can lead to inadequate heat transfer and negatively affect part dimensional properties, cosmetic finish, process efficiency and overall productivity."

In the latter case, manufacturing efficiency is lost when the mold needs to be cleaned more frequently. Psillakis reveals that buildup can be caused, either by an excess of release agent on the mold or lack of a release barrier, between the molded part and the mold surface. The latter may lead to a buildup from the material and/or byproducts and residues generated during the process.

Lorenz says, "If not formulated with the proper components, release agents can cause problems in post-cleaning and prepaint treatment operations. Included is buildup that can lead to discoloration or staining of the part."

Finn points out that manufacturers can encounter big problems with cleaning molded parts. He says, "We have seen in an aerospace application the manufacturer using 10 different release agents. As a result, a variety of different cleaners and methods need to be utilized which adds cost and inefficiency. The manufacturer would be better served

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using one release agent that can be cleaned by one standardized procedure.”

Finn also indicates that application of excess release agent can lead to leakage from the part onto the mold surface. He says, “This creates mold dirtiness leading to reduced operating life.” One application that caused this problem was a composite part consisting of clay reinforcing ethylene propylene diene M-class rubber (EPDM).

LAB TESTING

Due to the diverse types of applications and materials being molded, there are no standard lab tests for the evaluation of release agents. Lorenz says, “Various custom tests that involve spraying or applying release agent on metal dies at elevated temperatures are used. These custom tests look to evaluate and characterize the release agent film. The volume of gas evolved due to thermal decomposition of the release agent is measured to determine if it could cause poor casting porosity results which will affect performance.”

Lorenz reveals that thermogravimetric analysis (TGA) is utilized in the lab to determine the thermal stability of the release agent.

Finn indicates that release agent suppliers have the ability to simulate operations in-house. He says, “We can simulate the temperature and pressure conditions on the material be-

ing molded in the laboratory. This leads to the recommendation of one to two potential candidates for customer testing.”

Psillakis believes that testing of mold-release agents requires not only a strong knowledge of the chemistry of the various components used in formulating but also an understanding of material science. He says, “Expertise in material science is needed to determine how material flows along the molding stages, as it changes its physical state or chemical composition (in-mold reactions, cross-linking mechanisms) within the mold cavity geometry.”

MOLD COATINGS

One other approach to improve the performance of the mold-making process is to apply a coating. Steve Bales, president of Bales Mold Service, Inc., in Downers Grove, Ill., says, “The purpose of a mold coating is to provide lubricity, abrasion protection and corrosion inhibition. When a mold coating is devised, the user needs to determine what properties are required in order for the best possible choice to be made.”

David Bell, president of Minneapolis-based Phygen Coatings, Inc., adds, “A mold coating functions as a physical barrier between the steel mold and the part (mostly plastic) being processed. Modern plastics contain abrasive additives needed for durability, but these components wear out mold-

Properties and Applications of Representative Mold Coatings

Coating	Rockwell Hardness	Coefficient of Friction	Applied Temperature	Ideal Use	Molding Applications
Diamond-Chrome	85 + R.C.	0.15 or less	54 C	Excellent Abrasion Resistance	Moving Components, Locks, etc.
Electroless Nickel	50 R.C.	0.45 or less	85 C	Moderate Abrasion & Excellent Corrosion Resistance	Excellent Chemical Resistance Used in PVC Molding
Electroless Nickel - PTFE	45 R.C.	0.10 or less	85 C	Excellent Corrosion Resistance & Superior Lubricity	Excellent Release Properties for Difficult-to-Eject Polymers
Hard-Chrome	72 R.C.	0.20 or less	54 C	Good Abrasion Resistance	Abrasion Resistance Glass-Filled Materials
Nickel-Cobalt	62 R.C.	0.24 or less	54 C	Good Abrasion Resistance & Corrosion Protection	PVC Molding

Table 1 | Mold coatings are prepared by a cathodic vapor deposition process method. Users select the type of coating based on the need for abrasion resistance, corrosion protection and lubricity. [Courtesy of Bales Mold Service, Inc.]

critical surfaces faster. This leads to the need for the coating to protect the mold surface.”

The mold coating is deposited on the surface. Bales says, “The vast majority of coatings exhibit a thickness between 0.0002 and 0.0003-inch.”

Bell says, “Mold coatings are normally hard ceramics with hardness values two to three times higher than tool steel. These hard coatings are typically very inert substances that when applied properly can be structurally dense- and defect-free to provide good performance.”

Bales indicates that mold coatings are prepared from such substances as hard-chrome, diamond-chrome, nickel-cobalt and electroless nickel.² A list of representative coatings, their properties and applications are shown in Table 1.

Each mold coating is used in specific applications because it imparts unique characteristics. Bales says, “Hard-chrome and diamond-chrome are best suited for providing abrasion resistance. Plastic compounders are using more abrasive fillers (such as fiberglass and sawdust) to reduce costs. These components will wear out surfaces in injection molding processes unless a coating is used.”

One example of a mold material that exhibits superior abrasion resistance is shown in Figure 3. The core section shown is used to mold fiberglass material, according to Bales.

In contrast, a coating comprised of electroless nickel and polytetrafluoroethylene provides superior lubricity and exhibits a low coefficient of friction. Bales says, “This coating will operate to a temperature limit of 290 C. If higher stability is required, then a coating prepared with electroless nickel and boron nitride displays stability up to 650 C.”

Mold coatings are physically applied by a cathodic arc physical vapor deposition (PVD) process. Bell indicates that his company has developed a chromium nitride coating using the principle of arc plasma acceleration.³ This process

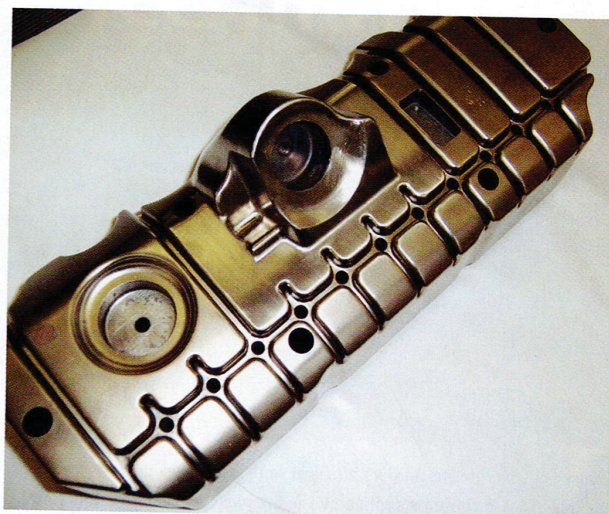


Figure 3 | One of the key properties of a mold coating is abrasion resistance. This is particularly important in applications such as this core section which is used to mold fiberglass material. [Courtesy of Bales Mold Service, Inc.]

enables a more uniform coating to be prepared that is denser than other coatings of the same chemical composition. He says, “The result is a coating that is more durable, displays good hardness, abrasion wear resistance and a low coefficient of friction. In addition, 90% fewer macro particle defects are observed in coatings prepared using arc plasma acceleration.”

The coating is composed of very fine grains that are 15 to 40 nanometers in diameter. Microscopic images showing a coating prepared from the arc plasma acceleration process vs. the conventional PVD process are provided in Figure 4.

One application benefiting from the arc plasma accelera-

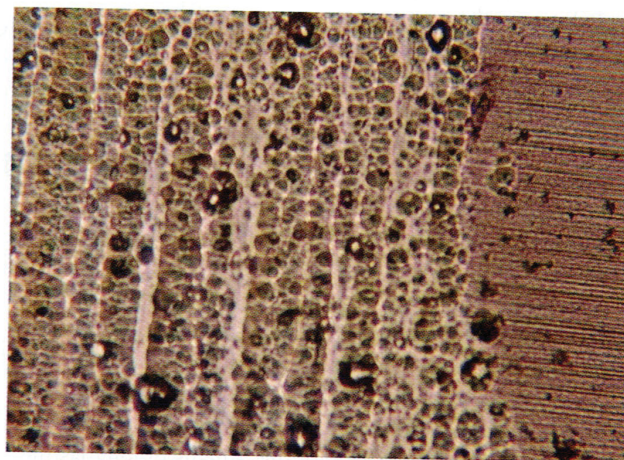
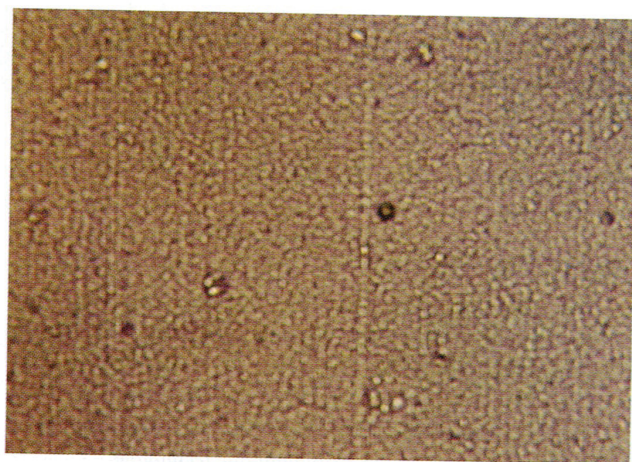


Figure 4 | Arc plasma acceleration produces chromium nitride mold coatings that are denser, more uniform and more durable. This figure shows a microscopic image of a chromium nitride coating prepared by arc plasma acceleration on the left vs. a conventional process on the right. [Courtesy of Phygen Coatings, Inc.]



Figure 5 | Complex automotive air filter housing are produced through the use of mold coatings applied by the arc plasma acceleration method. [Courtesy of Phygen Coatings, Inc.]

tion process was injection molding of complex automotive air filter housing (see Figure 5). Coatings prepared by the conventional PVD process could not handle this application without premature wear, according to Bell.

Accelerated wear testing was conducted using the Taber Abraser to show the superior performance of this technique. In this procedure, the coating is challenged by the rubbing of a silicon carbide wheel. The results showed that the chromium nitride coating prepared by arc plasma acceleration remains polished after 3,000 revolutions. In contrast, a conventional coating is removed by this method after only 200 revolutions.

Researchers at Argonne National Laboratories evaluated this coating for lubricity using the Cameron-Plint high frequency reciprocating rig. A 0.25-inch, 52100 steel ball was moved back and forth across the surface under a load of 10 newtons at a frequency of 3 Hz. They found that the chromium nitride coating displays coefficient of friction values as low as 0.09.

Bales sees the use of more automation by manufacturers as leading to the need for better mold coatings. He says, "Complex operations are being conducted that involve machines containing as many as 128 molds. Manufacturers need to balance the material going into these mold cavities and safely vent gases. Coatings such as nickel, blended with polytetrafluoroethylene and nickel boron nitride, are very useful in reducing friction, which enables molds to be filled faster under less injection pressure."

The result is lower cycle times and less worry about material sticking to the mold. Cycle times can drop by 0.5 seconds, which leads to much greater productivity.

Bell also believes that the challenge in using mold coatings is to show their enhanced productivity over long life cycles. He says, "Demonstration of the benefits of long-lasting mold coatings will help to persuade manufacturers that their use will provide better quality parts."

RELEASE AGENTS AND MOLD COATINGS

Mold coatings have reduced the need for release agents in specific applications. Bales cites the preparation of molded caps, which are prepared in machines containing between 64 and 128 cavities. He says, "It is very difficult to continuously spray multiple cavities with release agent and maintain productivity."

Bell indicates that mold-release agents remain useful in specific applications. He says, "We encountered an application that prepared soft buttons used in garage door devices. The addition of a release agent to the mold coating enabled the part to more easily drop out of the mold cavity."

Mold-release agents can complement mold coatings in many applications. Bell explains, "Good ceramic mold coatings improve release properties by themselves by preserving the surface topography of the mold. Release agents are used in practice to further improve the release."

The difference between coatings and release agents is that the former provides a permanent physical barrier that is hard to wear out or penetrate. In contrast, the release agent creates an easy-to-penetrate film that is easy to break in order to enable the finished part to separate from the mold.

Bell concludes, "No single coating can deliver unbeatable release properties and no single release agent can protect mold against wear and corrosion. A good combination of both can make the most to the mold performance."

Those applying mold-release agents and mold coatings face many of the same challenges as conventional automotive and industrial lubricants. Users are seeking good lubricity, abrasion protection and corrosion inhibition. Finished molded parts must meet rigid customer specifications. Technologies are moving to develop release agents that are more environmentally friendly and durable.

There are a lot of options for mold coatings. Further development will be spurred by the continuing demand for better performance. The growth of automation and movement toward better productivity with machines containing multiple molds means that a combination of release agents and coatings will be required to meet future customer requirements. **TLT**

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