A die cast mold release lubricant comprises a silicone compound. A method of application of the lubricant to a die cast mold as a release agent is disclosed where a die casting machine has a mold with mold halves forming a mold cavity when the mold halves abut against one another, a shot sleeve and a plunger which pushes molten material through the shot sleeve and into the mold cavity. The mold release agent is placed into the shot sleeve remote from the mold cavity, molten material is introduced into the shot sleeve, and the molten material and the mold release agent are forced into the mold cavity by movement of the plunger into the shot sleeve. The silicone compound preferably has a melting point of about 90-220°F, and a molecular weight of about 5500-50,000.
FIG. 1

FIG. 2
**MOLD RELEASE AGENT AND METHOD OF APPLICATION FOR DIE CASTING**

**RELATED APPLICATION**


**FIELD OF THE INVENTION**

[0002] This invention relates to improvements to pressure die casting mold release agents, and to an improved method of application of the mold release agent in the pressure die casting process.

**BACKGROUND OF THE INVENTION**

[0003] Pressure die casting is a well known process in which molten metal is forced under pressure and heat into a mold cavity of a mold of a die casting machine. The molten metal is introduced in a shot sleeve, and a plunger forces the metal into the mold cavity through a shot sleeve. While in the mold cavity the molten metal solidifies resulting in a molded part having a geometry conforming to that of the mold cavity. After the part is formed, it is then ejected from the mold cavity. Molded parts so produced have excellent dimensional tolerances, structural integrity and cosmetics.

[0004] There are at least two distinct classes of lubricants used in pressure die casting, each applied to a different area of the pressure die casting machine. One is a plunger lubricant, used for the "shot end" of the die casting machine; the other is a mold release lubricant, used for the mold cavity and adjacent area of the die casting machine. At the shot end of the die cast machine there are tight tolerances between the plunger tip and the shot sleeve. Friction may interfere with the efficient movement of the plunger through the shot sleeve. The plunger lubricant is applied to the plunger tip or immediately adjacent the plunger to provide hydrodynamic and boundary lubrication between the plunger and the shot sleeve and thereby enhance smooth travel and acceleration of the plunger through the shot sleeve. Plunger lubricants also provide a barrier film between the molten metal and the plunger to help prevent adhesion of the metal to the plunger and to help reduce washout of the shot sleeve.

[0005] While solidifying in the mold cavity, the molten metal will have an affinity for the surfaces of the steel mold halves. This can result in stuck castings, soldering or other damage to the molded parts. To help avoid these problems, the second class of lubricants, mold release lubricants, have been used to help ensure proper removal of the cast part from the mold cavity, and to lubricate parts in the mold cavity as well as any runner and gate areas of the mold. Mold release agents should be thermally stable at high temperatures (as they are routinely exposed to molten metal), should have good wetting properties, should provide a barrier release between the cast part and the mold cavity, and should enhance molten metal flow.

[0006] Therefore, in all known pressure die casting processes the mold release agent is required to lubricate the mold halves for proper release of the cast part, and the plunger lubricant is required to lubricate the plunger as it travels in the shot sleeve. Known plunger lubricants have been liquids comprised largely of a mineral oil and other organic or inorganic materials added to enhance hydrodynamics and/or boundary lubrication and to reduce friction between sliding surfaces. Materials used in plunger lubricants are noted for providing lubrication between moving surfaces, and have not been noted for providing the thermally stable function required of mold release agents.

[0007] U.S. Pat. No. 5,076,339 to Smith discloses a plunger lubricant formed as a solid, wherein the plunger lubricant comprises at least 40% wax. The waxes disclosed include ethylene bis(stearamide), diestearoyl ethylene diamine, paraffin waxes and polyethylene waxes that typically have a relatively low molecular weight of less than 1000. The solid wax lubricant is applied through the pour hole into a shot sleeve at the plunger. This solid plunger lubricant has found some commercial success for lubrication of the shot sleeve and plunger tip. However, a mold release lubricant is still required to be applied to the mold halves, just as with all other heretofore known plunger lubricants. Further, low molecular weight lubricants have problems if used as mold release lubricants for die cast parts where secondary operations are performed, such as painting.

[0008] U.S. Pat. No. 5,039,435 to Hanano discloses a pressure die-cast mold release agent formed as a powder, essentially a solid lubricant. It comprises three elements: a lubricant, an organic polymer, and a metal soap. The lubricant can be one of the organic polymer can be one of eight different materials: polyethylene, silicon resin, polypropylene, phenol resin, polystyrene, acrylate resin, epoxy resin and alkyl resin. The lubricant is coated with the organic polymer or the metal soap. The powdery mold release agent is applied to the mold cavity halves electrostatically and in a vacuum, requiring incorporation of expensive capital equipment.

[0009] The September-October 1972 issue of Die-Casting Engineer discloses an article by Radille which teaches a pore-free die casting technique. Here, air is drawn out of the mold cavity and replaced with oxygen. A solid lubricant is applied to not only the mold cavity, but also the plunger tip and to the shot sleeve. The composition of the lubricant is not defined, but it does state that "oily type lubricants cannot be used in the process." Petroleum oil based mold release lubricants (i.e., "oily type lubricants") have been used in the past, but have fell out of favor due to safety and environmental concerns.

[0010] U.S. Pat. No. 4,519,927 to Seiki discloses a synthetic engine oil comprising up to 98% various arylalkyl silicones having a low viscosity and therefore a relatively low molecular weight. Engine oils generally are not used for die cast lubrication due to the more extreme environment of die casting, which can include exposure to temperatures over 1300°F. At such temperatures low molecular weight materials such as those disclosed in Seiki may not provide adequate and uniform lubrication, especially in parts with relatively complex geometries.

[0011] Currently, almost all mold release agents for pressure die cast manufacturing are liquids. More specifically, conventional mold release agents are water-based emulsions which may contain waxes, oils, silicones, surfactants, anti foams, extreme pressure additives, rust inhibitors, and biocides. The mold release agent is combined with air under
high pressure and then directly applied onto the mold cavity through spray nozzles. Typically water comprises about 45-90% by weight of the composition of conventional concentrated mold release agents. In turn, the concentrated mold release agent is then diluted with additional water immediately prior to application to the mold halves. These water-based mold release agents have the advantage of good heat extraction and lubrication properties. However, the large amount of water creates enormous amounts of waste effluent which must be cleaned from the machine and which must be removed and treated at additional expense. Also, large amounts of water cause thermal cycling of the mold halves, significantly shortening mold life. In addition, uneven application of mold release agent can result in uneven temperatures across the mold, which may deleteriously affect part quality.

U.S. Pat. No. 6,040,278 to Kok et al discloses a two-part water-free die lubricant which can include silicone oil, vegetable oil or a mineral oil in combination with a wax. However, such two-component lubricants may not provide a continuous and uniform layer of lubricant on a die cast part, especially in molds with high temperatures and/or relatively complex geometries, as the waxes may pull to the hottest parts of the die. Also, the use of the waxes disclosed in Kok et al may be more likely to burn at high temperatures, resulting in environmental release and possible marring of the surface of the die cast part.

It would be desirable to have a mold release lubricant with little or no water while still maintaining good thermal balance and lubrication properties. Also, it would be desirable to provide a mold release lubricant which allows for secondary operations to be performed on the die cast parts, such as painting.

SUMMARY OF THE INVENTION

In accordance with a first aspect, a die cast mold release lubricant comprises a silicone wax, preferably a single component silicone wax compound. In accordance with another aspect a method of application of the lubricant to a die cast mold as a release agent is disclosed. The silicone wax compounds have a melting point of about 90-220°F, and a molecular weight of about 5500-50,000. A die casting machine has a mold with mold halves forming a mold cavity when the mold halves abut against one another, a shot sleeve and a plunger which pushes molten material through the shot sleeve and into the mold cavity. The mold release lubricant is placed into the shot sleeve remote from the mold halves, molten material is introduced into the shot sleeve, and the molten material and the mold release agent are forced into the mold cavity by movement of the plunger into the shot sleeve.

From the foregoing disclosure and the following more detailed description of various preferred embodiments it will be apparent to those skilled in the art that the present invention provides a significant advance in the technology and mold release agents for die casting. Particularly significant in this regard is the potential the invention affords for providing a high quality mold release agent which is environmentally friendly. Additional features and advantages of various preferred embodiments will be better understood in view of the detailed description provided below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic sectional view of a pressure die casting machine in which a mold release agent is used according to a preferred embodiment.

FIG. 2 is a schematic view of a pair of mold halves, showing the mold cavity, runners and inlet gate.

It should be understood that the appended drawings are not necessarily to scale, presenting a somewhat simplified representation of various preferred features illustrative of the basic principles of the invention. The specific design features of the method of application of as disclosed here, including, for example, the specific dimensions of the mold halves, will be determined in part by the particular intended application and use environment. Certain features of the illustrated embodiments have been enlarged or distorted relative to others to help visualization and clear understanding. In particular, thin features may be thickened, for example, for clarity of illustration. All references to direction and position, unless otherwise indicated, refer to the orientation illustrated in the drawings.

DETAILED DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

It will be apparent to those skilled in the art, that is, to those who have knowledge or experience in this area of technology, that many uses and design variations are possible for the mold release agent and method of application of the mold release agent disclosed here. The following detailed discussion of various alternative and preferred features and embodiments will illustrate the general principles of the invention with reference to a lubricant suitable for use with die-cast pressure molding of metal parts. Other embodiments suitable for other applications will be apparent to those skilled in the art given the benefit of this disclosure.

Referring now to the drawings, FIGS. 1 & 2 show part of a pressure die casting machine 8 suitable for forcing molten metal under some pressure and heat into a mold cavity 16 of a mold 10. The mold cavity is formed when a pair of mold halves 12, 14 abuts against one another, cooperating to form the shape of the part to be made from the molten metal. The molten metal is introduced in a shot sleeve 22 through, for example, pour hole 28, and a plunger 24 forces the metal into the mold cavity 16 through a shot sleeve. The molten metal may travel through a runner 18 and/or a gate inlet 20, as shown in FIG. 2, or in some preferred embodiments, the runner may not be used. The gate inlet 20, shot sleeve 22, plunger 24 and any runner(s) 20 are positioned outside of the mold cavity 16, and do not define the geometry of the part. Typically for the die casting process disclosed herein no vacuum is drawn and the mold cavity is not pressurized prior to introduction of the molten metal. Vents 30 may be provided to allow atmospheric air and entrapped gases to escape from the mold cavity 16.

Heretofore it has been thought by those in the art of pressure die casting that for die casting machines to operate properly, a plunger lubricant needed to be applied (either at pour hole 28 or immediately behind the plunger 29), and a mold release lubricant must be applied directly onto the surface to be lubricated. However, in accordance with a highly advantageous feature, the inventors have determined that a mold release agent of some compositions may be
applied to the gate, the runner, or to the shot sleeve, or to any combination therewith, (i.e., remote from the mold halves and also remote from the pour hole) and yet still function properly to lubricate the mold halves and permit release of the cast part from the mold cavity. Essentially, the metal pushes the mold release agent in front of it, forming a lubrication front that coats the mold halves as it travels through the mold cavity. This method of application advantageously can reduce the total amount of mold release agent that needs to be applied, reducing costs for the die owner.

The mold release lubricant may also be applied to the mold halves, as needed. Additional savings may be realized by reducing waste effluent. Further cost reductions may be obtained through shorter cycle times since less lubricant needs to be applied and the mold release of the present invention may be applied more rapidly than known mold release agents.

0022 The lubricant used in the mold release agents disclosed herein can advantageously be one of many types of low friction materials providing good thermal stability endurance and having either solid, liquid or wax-like properties and good wetting and adhesion properties. Lubricants suitable for use herein can comprise, for example, waxes of silicones, olefins and organic esters. The die cast mold release agents may optionally be formed as a solid or flexible gelatin-like material encapsulating a liquid and applied as a series of beads.

0023 Silicones comprise a wide variety of polymers that have alternating silicon and oxygen atoms in repeating disiloxane groups. Such silicones may also incorporate one or more organofunctional groups. Alkyl functional groups having at least 18 carbons are typically required on the side groups of polysiloxane chains to form a wax instead of oil. Examples of silicone wax compounds are DC-2503 silicone and DC-2-5088. Olefins generally comprise any unsaturated aliphatic hydrocarbon with one or more double bonds, and two hydrogens for every carbon (e.g., polymerized ethylene or butene). Olefins can comprise polyalphaolefins, alpha olefins and normal alphaolefins and polybutenes. Polyolefins are often a large component of synthetic oils. Examples of suitable materials are Petro-Canada API Group Ill and IV Oils; Durasyn 162 supplied by Amoco; Sylantom PAO 100 supplied by Crompton Corporation; Indopel H-100 by BP Amoco. Organic esters suitable for use as a lubricant here can comprise, for example, succrose esters of fatty acids such as Sevose® by Procter & Gamble, carboxylic acid esters, methyl esters such as Keil’s Base ML, methyl canola esters and methyl tallowate esters. Suitable waxes often at least partially comprise carboxylic acid esters, oxidized polyethylene, ethylene acrylic acid copolymers, bis-stearamide wax or microcrystalline wax.

0024 As there is no need to spray this mold release agent over the mold halves 14, 16, the mold release agent can comprise a significantly small amount of water compared with current known mold release agents. Preferably the mold release agent comprises essentially no water. For example, the mold release agent can be comprised of essentially entirely silicone wax with no water, advantageously eliminating the need to add water to a lubricant. No water is understood here to mean essentially water free, that no water is added to the lubricant. Of course, small amounts of water may be present as a result of exposure to the atmosphere, but this would usually be well less than 1% of the total composition of the water-free lubricant.

0025 Preferably the mold release agent would be applied remote from the pour hole in the area of the shot sleeve 35 shown in FIG. 2, and most preferably immediately adjacent the runner 18 as shown by arrow 36 in FIGS. 1-2. It has been found that such application positions are most effective in lubricating the mold halves 12, 14 so that the part created can be properly released from the mold cavity 16. Depending on the intended application, the mold release agent application location can be the shot sleeve, pour hole, and/or any runner and gate inlet connecting the shot sleeve to the mold cavity that is remote from the plunger.

0026 Most preferably a single component silicone wax with alkyl side groups of at least 18 carbons can be used as a die cast release lubricant. Single component is understood here to mean a lubricant having a composition greater than 95% formed from a single material. Single component silicone waxes are more advantageous than multi-component lubricants for uniform lubricant application particularly with molds subjected to high temperatures and/or having complex geometry. Also, some waxes used in known multi-component lubricants, such as some polyethylenes, polybutenes, polypropylenes, and ethylene-propylene copolymers may have some increased environmental release, especially at high temperatures.

0027 The single component silicone wax preferably has a relatively low melting point, in the range of 90-220° F, as it has been found that lower melting point waxes reduce the likelihood of solidification of the lubricant in vent holes of the mold. Also, preferably the wax has a molecular weight in the range of about 5500-50,000. A wax with too low a molecular weight, such as the silicone wax methyl hydrogen polysiloxane with a molecular weight around 2800, increases the likelihood that the die cast parts made using this lubricant will be difficult to paint. In particular, problems with low molecular weight waxes include surface adhesions and other surface irregularities including “fish eyeing” and an “orange peel effect.” A wax with too high a molecular weight exhibits properties less like a silicone material and more like a hydrocarbon or organic, and staining and material buildup on the die cast parts can result.

0028 Examples of silicone waxes with the appropriate combination of material properties are shown in the table below:

<table>
<thead>
<tr>
<th>Silicone Wax</th>
<th>SF-2W</th>
<th>SF-3W</th>
<th>SF-4W</th>
<th>SF-5W</th>
<th>SF-8W</th>
<th>SF-9W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt Point</td>
<td>90.8°F</td>
<td>110.6°F</td>
<td>129.8°F</td>
<td>107.6°F</td>
<td>128.8°F</td>
<td>161.2°F</td>
</tr>
<tr>
<td>Molecular Wt.</td>
<td>12721</td>
<td>13884</td>
<td>15794</td>
<td>13487</td>
<td>14836</td>
<td>19935</td>
</tr>
</tbody>
</table>
Thus single component silicone waxes with the given melting point range and molecular weight have been found to be highly advantageous for use as a die cast lubricant.

From the foregoing disclosure and detailed description of certain preferred embodiments, it will be apparent that various modifications, additions and other alternative embodiments are possible without departing from the true scope and spirit of the invention. The embodiments discussed were chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to use the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

What is claimed is:
1. A die cast release agent for lubricating a die cast mold comprising, in combination:
   a silicone compound having a molecular weight from about 9,000 to 50,000 comprising at least 95% by weight of the die cast release agent.
2. The die cast release agent of claim 1 wherein the silicone compound has a melting point from about 90-220°F.
3. The die cast release agent of claim 1 wherein the silicone has alkyl side groups.
4. The die cast release agent of claim 3 wherein the alkyl side groups have at least 18 carbon atoms.
5. A die cast release agent for lubricating a die cast mold comprising, in combination:
   at least 95% by weight of a silicone compound having a melting point from about 90-220°F.
6. A die casting method for making a part in a die casting machine having a mold with mold halves forming a mold cavity when the mold halves abut against one another, a shot sleeve with a pour hole to receive molten material, and a plunger which pushes molten material through the shot sleeve and into the mold cavity comprising, in combination, the steps of:
   placing a mold release agent into the shot sleeve remote from the mold cavity;
   introducing molten material into the shot sleeve; and
   forcing the molten material and the mold release agent into the mold cavity by movement of the plunger into the shot sleeve, wherein the mold release agent comprises a silicone compound.
7. The method of claim 6 further comprising the step of applying the mold release agent to a runner connecting the mold cavity to the shot sleeve.
8. The method of claim 6 further comprising the step of applying the mold release agent to a gate inlet connected to the mold cavity.
9. The method of claim 6 further comprising the step of applying the mold release agent at the mold halves.
10. The method of claim 6 further comprising
    a runner connecting the mold cavity to the shot sleeve;
    wherein the molten material is introduced adjacent the runner.
11. The method of claim 6 wherein the mold release agent is further applied remote from the pour hole.

* * * * *