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METAL CASTING IN A PROTECTIVE ATMOSPHERE

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The present invention relates to a method for teeming or pouring molten metal into a pre-formed mold cavity provided with a gaseous protective atmosphere. It relates more particularly to a metal casting method in which the mold cavity is purged with an inert gas to provide a non-oxidizing and non-reactive atmosphere during the metal teeming operation.

During a pouring or teeming operation, many of the recently developed space age metals will combine in the molten state with common gases such as oxygen, nitrogen, water vapor and hydrogen, and often the so-called neutral atmosphere gases such as carbon monoxide and carbon dioxide. Because of their chemical properties, these metals have become generally known as "reactive" metals. When the metals combine with one or more of the above-mentioned gases, the frequent result is impairment or destruction of the metal's important properties. In the production of titanium, for example, very small amounts of dissolved nitrogen in the metal have been found to destroy the metal's ductility.

Not only must the reactive metals be protected in the pure state, but just as important, in the alloy or alloy addition form. One of the more critical areas is the production of aircraft quality steels where increasing requirements have placed a premium on cleanliness. Aircraft quality steels in particular are generally evaluated on the basis of their relative lack of non-metallic inclusions. Non-metallic oxide inclusions as a result of oxidation during a teeming operation are extremely detrimental in this application since they cause drastic reductions in the physical properties of the metal.

In order to maintain a high quality metal at minimum cost, argon or a similar inert gas is frequently used to envelope the molten metal stream during the teeming step. In this process an ingot mold to use an example, is purged with argon or a similar inert gas and the molten teem stream is then surrounded by a curtain of argon as the stream enters the mold. Thus, under ideal conditions, the molten metal is completely shielded from contact with the atmosphere. An argon casting operation of this sort is found to be effective in three general areas of application. First, with steels which are accepted on the basis of cleanliness, argon casting minimizes non-metallic inclusions. Second, inert-atmosphere protection reduces conditioning losses by decreasing surface oxidation during teeming. Thirdly, the effects of special vacuum treatments are preserved where the steel is vacuum degassed, then teemed from the ladle. The inert atmosphere when provided, eliminates the reaction between molten steel and oxygen, nitrogen, or water vapor which would otherwise partially nullify the effects of vacuum treatment.

Purging in the argon casting process takes advantage of argon's greater-than-air density to establish an inert atmosphere economically in the mold cavity. Purging can be accomplished by either a dilution or displacement process. Dilution purging is generally by its nature the most wasteful and uneconomical way of eliminating air from the mold. The purge gas according to this method, is introduced through a straight pipe at high velocity to the mold cavity where said gas thoroughly mixes with the chamber atmosphere. The atmosphere gases along with a portion of the purge gas is then exhausted from the cavity. With a dilution purge experience has shown that 7 to 10 mold cavity volumes of purge gas are required

to reduce the oxygen content in the chamber to less than 0.25 percent. The high volume of purging gas required by this method represents excessive costs.

An alternate and more efficient gas purging method utilizes a displacement purge and generally employs argon. In this method the gas is introduced at the bottom of a mold and distributed as to form an upward moving front much like a piston. This front on rising tends to displace the mold atmosphere which is vented through the top of the mold. The latter technique constitutes a substantial economic improvement over the prior dilution method since only about 1⅔ mold cavity volumes of purge gas is required to reduce the oxygen content in the cavity to less than 0.25 percent.

The ideal displacement purge would of course require only one mold volume of inert gas to establish a completely inert atmosphere. A primary drawback associated with the above-mentioned displacement purging operation is the cumbersome but necessary equipment required and the necessity of sealing the mold twice. Briefly, in this purging method, the top of the mold is first covered with a frangible sheet of aluminum or a similar metallic foil which provides a closure and is sealed around the mold. Next a sharp nosed purging sparger is inserted into the mold by piercing the aluminum foil is order to deposit the purge gas at the mold bottom. Finally, after the purging is completed, the apparatus must be removed and the hole in the foil resealed. The purging operation to be successful must be closely coordinated with the teeming operation in order to minimize the amount of argon consumed and the amount lost prior to teeming.

It is therefore an object of the invention to provide an improved method for mold casting metallic objects in which the mold cavity is provided with a non-oxidizing or non-reactive atmosphere during the metal teeming period.

A further object is to provide a method for purging a mold cavity of oxidizing atmosphere prior to the introduction to said cavity of a molten metal stream, which method is highly effective as well as economical in the use of a protective gas.

Still another object is to provide an economical mold cavity purging by an improved displacement method in which the amount of inert gas used for said purging does not substantially exceed the volume of the mold cavity.

In brief, the invention contemplates an improvement in the casting of molten metal objects which consist of: providing a mold having a formed hollow cavity therein defining the configuration of the object to be cast, providing in said cavity a flexible walled frangible container adapted to hold an inert gas, supplying the inert gas to the container at a slightly elevated pressure to expand the container walls outwardly into contact with the cavity walls thereby completely occupying said mold cavity, directing a stream of molten metal against said frangible container and into the cavity whereby the container will be punctured by said stream to release the gas into the cavity, and thereafter continuing the metal stream to fill the cavity and displace the inert gas whereby said molten metal will be prevented from contacting the atmosphere during said metal pouring or teeming period.

In practicing the invented method, a mold into which the molten metal is poured may consist of any one of several embodiments familiar to the art. Among the most common of such molds is the type normally used for the pouring of or casting of steel ingots. These molds are generally elongated, having an internal cavity formed of slightly divergent inner walls, with an opening at the top of the cavity to receive a stream of the metal. In order to simplify the following discussion of the process, the details of structure and operation will be described as applied to the above-mentioned ingot type of mold.

It is not intended of course that the present concept should be confined to the casting of ingots or similar shapes, since the method is adapted under the proper conditions to virtually any sort of mold. For example, the method is readily employed in the instance of bottom poured molds in which the molten stream enters the lower cavity portion of the mold by way of means other than the top opening, and on rising displaces the purging gas. Also, the purging method is adapted for use with sand casting molds.

In its simplest form, the method provides that a mold cavity be furnished with a container adapted to hold a supply of an inert purging gas approximately equivalent to the mold volume. To properly function, the container must be substantially gas impermeable and yet must also be thin, flexible and frangible so as to be instantaneously piereced when contacted with the molten stream. For example, the container may be pre-formed of separate panels with gas-tight seams or it may be molded in a single unit. In either instance, the disposition of the container when inflated must substantially conform to the configuration of the mold cavity in order that the atmospheric air will be completely evacuated.

While the purge gas holding receptable is herein referred to as a container, it may readily assume the form of an inflatable bag or bladder or even a collapsible, inflatable carrier made from a metal such as aluminum foil.

A preferred embodiment of the gas container consists of a balloon-like plastic bag or sack being outwardly expandable to the desired inflated shape, yet made from a material that will not stretch materially under a contained pressure slightly greater than ambient. When made of a plastic material such as polyethylene, the temperature of the hot molten metal stream will cause the bag to vaporize and pass off in harmless fumes. For this reason, it is not desirable, though not prohibitive, to utilize a material such as polyvinyl chloride film which on being melted, will form toxic gases within the mold. To avoid undesirable additions to the molten metal such as carbon released from the vaporized container, wall thickness is minimized. Ideally, the inflatable container material is made sufficiently thin to retain its flexibility yet withstand a slight amount of abrasive rubbing against the rough mold cavity wall. It has been found that under ordinary conditions a polyethylene bag thickness of between .002 and .004 inch will withstand the expected abuse and not cause excessive carbon addition to the poured metal.

While an inflatable paper or cellulose type container might be adapted to the process, these materials are generally undesirable and pose problems not associated with plastic containers. Another material found to be satisfactory in the process is Mylar, or polyethylene terephthalate. An inflatable container made from this material will withstand mold cavity temperatures up to about 350° F. On the other hand, when using polyethylene, the mold has to be maintained below about 200° F. to avoid premature melting.

While the container material may be either inelastic or elastic, elasticity is not desirable since the pressure of the purging gas when contained should be equal to or only slightly greater than atmospheric. The reason for limiting the pressure of the gas prior to the container being vaporized is that the release of the gas should not be explosive but rather without undue turbulence. Ideally, as the bag is contacted and punctured by the metal stream, it will vaporize thereby permitting the contained gas to remain settled in the mold cavity.

The particular purge gas employed must, in addition to displacing the mold atmosphere, provide the desired non-oxidizing or non-reactive atmosphere into which the molten metal is immersed. A suitable atmosphere for this purpose may be made up of a mixture of several gases in a desired proportion according to the metal and the pouring method. It is generally preferable to use a purging gas having a density approximating the surrounding atmosphere or somewhat heavier. Under these conditions, the purging gas will tend to remain in the mold until upwardly displaced therefrom by the rising metal.

Where the previously mentioned bottom pouring method is employed, the metal does not enter the mold at the top opening but is rather introduced through a supplementary passage in the vicinity of the mold bottom. The purging gas container in this instance may still be used to fill the mold cavity until it is caused to evaporate by the hot metal. Here though, it is possible to use an inflating or purging gas having a density less than that of the atmosphere. Thus, by introducing the molten metal at a sufficiently rapid rate to the mold bottom, it is possible to fill the mold cavity prior to the complete evacuation of the purge gas through a vent means communicated with the mold upper end.

As mentioned above, according to the practice of the invention the vaporizable gas container of proper size and shape to fill the mold may be inserted into the mold in a collapsed condition and thence inflated with a purge gas. For molds having a uniform shape and relatively parallel sides such as an ingot mold, it has been found satisfactory to first inflate or partially inflate the container prior to insertion into the cavity. It may be readily seen that the preinflation of a large number of containers provides a desirable economic and operational advantage especially in the instance of a metal-casting operation in which a great number of similarly shaped castings are to be made in one pouring operation.

The inflation means employed may be a standard form of equipment such as a supply of the purge gas in pressure regulated tanks or from a piped supply. It is essential, though, that upon filling the gas container, the inflating pressure should not be greatly in excess of the atmospheric pressure. In test runs using a polyethylene inflatable bag, an internal pressure of about 0.5 pound per square inch above atmosphere has been found to be adequate to expand the container walls into contact with the mold cavity.

A further precautionary measure is the need for displacing the mold gas from the container by inflating the latter such that the lower portions expand first thereby avoiding entrapment in the cavity of the gas to be purged. The technique employed in this respect is of course commensurate with the particular mold shape and the material of which the container is fabricated.

In practicing the invented method, the gas container may be inserted into a mold cavity in a collapsed or inflated condition although the former is preferred. This usually is done by first providing the mold with a metal hot top having a top opening in accordance with present metal casting practice. Next, the inflatable container is supported in such a manner that it extends fully into the mold cavity with the open end or access opening positioned on the hot top. Prior to the actual teeming operation, a conduit or similar filling means connected to a supply of purging gas is inserted into the container opening. In the instance of argon, the purge gas will then flow to the bottom of the container thereby outwardly expanding the lower walls into contact with the mold cavity lower portions. As the argon flow continues, the container will be inflated from bottom to top and completely displace the cavity gases. Filling in this manner is continued until the hot top opening is occupied; thereafter the container may be sealed closed. This operation may be done well in advance of teeming, as the container will maintain the purity of the enclosed gas.

To further the provision of a non-oxidizing or non-reactive atmosphere during the metal teeming operation, a frangible gas-tight closure may be fastened across the top of the mold. An embodiment of this closure may consist of a thin metallic sheet such as aluminum foil. The closure provides an additional advantage to the process by confining the entire mold interior until the teeming operation.

After positioning the metal pouring ladle over the mold, a further argon atmosphere may be established between the mold and the ladle. It has been found for this purpose that an elongated cylindrical closure extending between mold and ladle and surrounding the metal stream, will provide the desired protection. When this closure is provided with a dynamic argon atmosphere, the tendency to aspirate air into the mold cavity by the down-flowing metal stream is minimized.

When the stream is released from the ladle, it will puncture the foil closure, contact the purge gas containing bag and enter the mold cavity. As the metal level rises in the mold, the purge gas will be upwardly displaced through the hot top opening and the foil closure thereby maintaining the argon-free atmosphere about both the teem stream and the molten pool.

It may be seen that one of the advantages inherent to the invention is the ease and convenience of operation it affords. For example, by using prefilled bags of the purging gas it is possible to evacuate a mold cavity much in advance of the teeming operation. Therefore is it no longer necessary to purge immediately prior to teeming thus eliminating what was formerly a dangerous operating hazard.

It is not intended that the invention be limited to the foregoing description since modifications may be made in the process by one skilled in the art without exceeding the spirit and scope of the invention.

What is claimed is:

1. A metal casting method which comprises the steps of: providing a casting mold having a cavity therein defining the contour of the object to be cast, providing said cavity with a frangible walled gas container holding a supply of a non-reactive purge gas, the walls of said container being expanded into contact with the mold cavity walls, and thereafter introducing a stream of the molten metal into said mold cavity to pierce the container wall and permit the molten metal to fill the cavity in non-reactive atmosphere.

2. A process for casting metal objects by depositing a stream of the molten metal in a mold therefore which comprises: providing a mold having a hollow cavity therein defining the configuration of the object to be formed, providing said cavity with a gas tight container vaporizable at the temperature of the molten metal holding a supply of non-reactive metal protecting gas in an amount approximating the volume of the cavity and at a pressure slightly greater than atmospheric thereafter directing a stream of the molten metal into said cavity to vaporize the container thereby permitting the gas to occupy the mold cavity until displaced therefrom by upward rising metal.

3. A metal casting method which comprises the steps of: providing a casting mold having a cavity therein defining the contour of the object to be cast, providing said cavity with a thin walled gas inflatable bag having outwardly expandable walls substantially conforming in shape to the contour of said cavity, inflating said bag with a non-reactive gas to outwardly expand said walls into contact with the mold cavity thereby displacing air from said cavity, and thereafter introducing a stream of the molten metal into said mold cavity to pierce the bag whereby the molten metal stream will be shielded by the non-reactive gas from contact with the ambient atmosphere about the mold.

4. A method substantially as described in claim 3 wherein the inflatable bag is made from a material vaporizable at a temperature of about 1000°.

5. A method substantially as described in claim 3 wherein the inflatable bag is formed of polyethylene.

6. A method substantially as described in claim 3 wherein the inflatable bag is polyethyleneterephthalate.

7. A method substantially as described in claim 3 wherein the gas is argon.

8. In the casting of metal objects wherein a molten metal is deposited into a preformed mold to form said object, the improvement for eliminating from said metal object blow holes and surface inclusions which comprises the steps of: providing a mold having a top opening including a cavity in the mold defining the configuration of the said object, providing said cavity with a thin-walled vaporizable container having outwardly expandable gas tight walls adapted to conform on being expanded to the cavity configuration, inflating said container with a sufficient amount of an inert gas having a density greater than the density of the atmosphere surrounding said mold to expand the walls of the container into contact with the cavity walls thereby displacing air contained in the cavity, directing a stream of the molten metal into said cavity to vaporize the container, and continuing said stream of molten metal to fill the cavity and displace the purge gas upwardly therefrom as the level of said molten metal rises in the cavity.

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