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(54) **In-situ semi solid metal slurry formation and delivery apparatus and method**

(57) An embodiment of the presently claimed invention includes an in-situ slurry formation apparatus (10) mounted to die casting machines to convert liquid metal to semi-solid metal (SSM). Thus, there is no need to modify existing machines or change the cell layout to accommodate more space than would otherwise be necessary. These machines also need not be replaced with machines specially designed for SSM. Further, a method

for converting molten metal to semi-solid metal includes coupling a conduit to a die casting machine, wherein the conduit comprises an inlet, an outlet and a body disposed between the inlet and the outlet, regulating the conduit's temperature, surrounding the conduit with a housing, inserting molten metal at the inlet, cooling the molten metal to semi-solid metal in the body, and expelling semi-solid metal from the outlet.

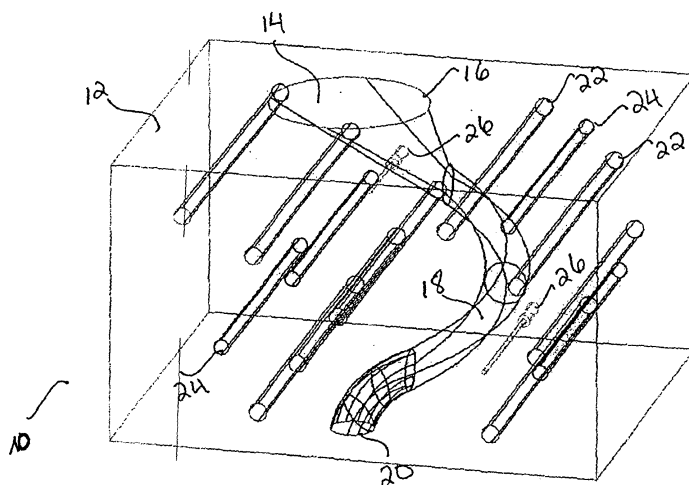


Fig. 1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to provisional patent application entitled, IN SITU SLURRY FORMATION AND DELIVERY TO DIE CAST MACHINES, filed August 23, 2005, having a serial number of 60/710,165, the disclosure of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to casting metal alloys. More particularly, the present invention relates to semi-solid metal casting.

BACKGROUND OF THE INVENTION

[0003] Casting complex geometries may yield products with undesirable shrink porosity, which can adversely impact the quality and integrity of the cast part. Shrink porosity defines a condition that arises as a metal part begins to shrink as it cools and solidifies along the outer surface, leaving pockets of air (referred to as "voids") trapped in the center of the part. If the voids are not reconstituted with the metal, the cast part is termed "porous." This condition is prevalent with the use of aluminum alloys as the casting material.

[0004] Semi-solid metal casting (SSM) may be used to address this problem of porosity in cast products, particularly for aluminum alloys. Advantages to SSM casting include producing high quality parts with structural integrity, rigidity, strength and ductility.

[0005] As such, it is desirable to use SSM methods as often as feasible. Therefore, it is desirable to provide a mechanism to allow die casting machines the ability to use SSM metals without replacing them or undergoing costly modifications to existing machines.

SUMMARY OF THE INVENTION

[0006] The foregoing needs are met, to a great extent, by the present invention, wherein in one aspect an apparatus is provided that in some embodiments a mechanism to allow die casting machines the ability to use SSM metals without replacing them or undergoing costly modifications to existing machines.

[0007] In accordance with one embodiment of the present invention, an apparatus for converting molten metal to semi-solid metal includes a conduit having an inlet and an outlet to transport the molten metal, and a temperature regulator disposed adjacent the conduit to regulate the temperature of the molten metal, and a housing surrounding the conduit and the temperature regulator.

[0008] In accordance with another embodiment of the present invention, a method for converting molten metal

to semi-solid metal includes coupling a conduit to a die casting machine, wherein the conduit comprises an inlet, an outlet and a body disposed between the inlet and the outlet, regulating the conduit's temperature, surrounding the conduit with a housing, inserting molten metal at the inlet, cooling the molten metal to semi-solid metal in the body, and expelling semi-solid metal from the outlet.

[0009] In accordance with yet another embodiment of the present invention, a system for converting molten metal to semi-solid metal includes means for coupling a conduit to a die casting machine, wherein the conduit comprises an inlet, an outlet and a body disposed between the inlet and the outlet, means for regulating the conduit's temperature, means for surrounding the conduit with a housing, and means for cooling the molten metal to semi-solid metal in the body.

[0010] There has thus been outlined, rather broadly, certain embodiments of the invention in order that the detailed description thereof herein may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional embodiments of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0011] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of embodiments in addition to those described and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

[0012] As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is an illustration of an in-situ slurry formation apparatus according to an embodiment of the present invention.

[0014] FIG. 2 is an illustration of a HPDC die casting machine having the in-situ slurry formation apparatus incorporated therein.

[0015] FIG. 3 is a detailed representation of the in-situ slurry formation apparatus configured for the HPDC machine of FIG. 2.

[0016] FIG. 4 is a representation of a HVSC die casting machine having the in-situ slurry formation apparatus incorporated therein.

[0017] FIG. 5 is a detailed representation of the in-situ slurry formation apparatus configured for the HVSC machine of FIG. 4.

[0018] FIG. 6 is an illustration of the microstructure obtained for a 356 alloy.

[0019] FIG. 7 is an illustration of the microstructure obtained for a 206 alloy.

DETAILED DESCRIPTION

[0020] The foregoing needs are met, to a great extent, by the present invention, wherein in one aspect an apparatus is provided that in some embodiments combines various methods of die casting with semi-solid metal in an efficient manner. There are, of course, additional embodiments of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0021] Casting methods such as die casting, gravity permanent mold casting, and squeeze casting have been used for Aluminum-Silicon (Al-Si) alloys. In thixocasting semi-solid metal casting (SSM), specially prepared metal slugs are gradually brought to a semi-solid state, then transferred to the casting machine, where a ram uses pressure to inject the SSM into a die. Once solidified, the die opens and the cast part is ejected. With SSM, the viscosity is fairly high so the injection speed is lower than with conventional pressure die casting. This results in little or no turbulence, which reduces porosity. In rheocasting SSM, the SSM slurry is made from the liquid state. In an embodiment of the present invention, the rheocast SSM process is performed.

[0022] Die casting is a manufacturing process wherein a strong, durable and intricate product can be mass produced. Die casting is also referred to as high pressure casting and has the unique ability to transform raw material into a finished form in the shortest possible cycle time. Often the finished product requires no additional machining or other operations. Die cast products are also dimensionally stable. Die casting is an efficient, economical process allowing for a broad range of geometries, high speed production and closer tolerances that provide heat resistant, stronger products. Thin wall castings are stronger and lighter than products produced using other casting methods.

[0023] FIG. 1 is an illustration of an in-situ slurry formation apparatus 10 according to an embodiment of the present invention. The in-situ slurry formation apparatus 10 is configured with and includes a funnel block 12. The funnel block 12 includes a funnel 14, heaters 24, coolers 22 and temperature sensors 26. The funnel 14 has generally a funnel shape with one end having a larger diameter than another end, although any other type of configuration may be used. The funnel 14 is used to transport and cool a liquid metal from a liquid metal source to a die casting machine. Liquid metal is poured into the funnel 14 at an inlet 16 and passes through the funnel 14 through a metal flow path 18. The metal flow path 18 can be as

long or short and have various turns as required, as long as it allows the liquid metal to cool down to a semi-solid metal state or as close as desired by a user. As the metal passes through, it cools to SSM state, or near SSM state, and exits the funnel 14 at an outlet 20.

[0024] The funnel 14 is maintained at a steady state temperature by using both coolers 22 and heaters 24 placed at various locations throughout the funnel block 12. The coolers 22 are pathways in the funnel block 12 whereby a cooling medium is passed. For example, oil, coolant or water may be used as the cooling medium. Other types may also be used. The cooling medium may flow through the passages or be contained statically therein.

[0025] The cooling passages may be combined with a water chiller that pumps and cools the cooling medium. Also, a re-circulatory system can be used to pump water through and then provide a tower that allows the water to cool. If heaters are selected, they can be used in conjunction with a cooling medium.

[0026] An alternative system may also be used to maintain the funnel 14 at a steady state temperature. A hot oil system offers similar capabilities as a water chiller. Also, an advantage of using hot oil instead of water is that the hot oil may heat the funnel as well as cool it, eliminating the need for separate heaters. The hot oil may further maintain a higher set temperature than could be maintained with a water system. The hot oil system or water cooler/heater system may be used to heat or cool the funnel as required by the user.

[0027] Heaters 24 may be cartridge heaters or any such heating device as may be appropriate. Temperature sensors 26 are placed in the funnel block 12 to determine and regulate the temperature. The temperature sensors 26 may be thermocouples or any such temperature sensor as may be convenient. To keep the temperature at a set range, thermocouples may be used in the system to monitor the temperatures.

[0028] These temperature sensors 26 send the temperature signal to a controller (not shown). This controller has a preset temperature range that is the desired temperature range for the process. If the signal received from the temperature sensors 26 is below the range, the controller signals to a relay which will allow for power to run through the heaters 24 and heat the funnel block 12. If the temperature exceeds the range, the controller can be used to send a signal to the relay that opens and closes a valve, letting the cooling medium run through the coolers 22. When the temperatures fall back inside the range, the heating or cooling may be turned off. If the temperature is in the preset temperature range, no cooling or heating may be necessary. A similar process, using a controller, would be followed if the hot oil system is used.

[0029] The funnel block 12 and the outlet 20 can be configured to mate with various die casting machines. Some examples of die casting machines are discussed below, and are not limited to these machines. The size

of the funnel block 12 depends on the amount of metal to be poured through and the amount of heat to be removed. For example, the funnel block 12 may be approximately 7.375 inches tall, 10 inches wide and 11.5 inches in length. The funnel block 12 dimensions may vary as necessary.

[0030] The funnel block 12 may be attached to the die casting machines using mounting brackets or any such means as is desired and feasible. The funnel block 12 may also be welded to the die casting machine.

[0031] Aluminum adheres to steel and other metals and has a tendency to oxidize and form a thin layer of oxidized aluminum upon contacting such metals. The layer of oxidized aluminum may flake off and enter the metal stream. Other contaminants may also enter the metal stream. To minimize or eliminate this problem, a non-wetting coating may be applied to the inside surface area of the funnel 14 to prevent oxide accumulation. There are several types of coatings that are available, for example, tungsten thermal coatings, boron nitride coatings and ceramic coatings. These coatings prevent the aluminum from oxidizing. To further prevent metal contamination, the funnel 14 may be separated at parting line with the use of automation to allow for blow off. Other methods of preventing contamination may also be used.

[0032] An embodiment of the presently claimed invention includes the in-situ slurry formation apparatus 10 mounted to machines without the need to modify the existing machines or change the layout to accommodate more space than would otherwise be necessary. These machines also need not be replaced with machines specially designed for SSM.

[0033] High pressure die casting (HPDC) at forces exceeding 4500 pounds per square inch also allow for liquid metal squeeze casting and SSM die casting. Squeeze casting is a method by which molten alloy is cast without turbulence and gas entrapment at high pressure, to yield high quality, dense and treatable components. In contrast, SSM uses semi solid metal billets cast to provide dense heat treatable castings with low porosity. Thus, products may be cast using either SSM casting or liquid metal squeeze casting.

[0034] Die casting produces complex shapes at lower costs. The use of semi-solid metal or liquid slurry metal as described herein over conventional molten metal reduces fluid turbulence when injected into the die. In this manner, the amount of air that is sequestered within the final part is reduced. Less air in the final part lends greater mechanical integrity and allows cast products to be heat treated. In addition, metals that are SSM cast require less heat which reduces cost and improves longevity of the molds and dies.

[0035] The microstructure of SSM cast products can determine the mechanical properties of the product. As such, the microstructure can be manipulated to achieve desired results. One way to manipulate the final microstructure of an SSM cast part is to control the time the metal remains in the SSM range. That is, the amount of

time the metal spends in the shot sleeve before it is injected into the molds can be regulated or optimized for a desirable microstructure. Alternatively, molten metal at a predetermined temperature may be poured into the shot sleeve of shuttle presses, i.e. presses that lack an indexing feature.

[0036] HPDC is a large volume, high productivity process for the production of complex thin walled castings with part weights ranging from a few grams to more than 15 kg. HPDC has been known for the production of housings and other automotive front end structures and instrument panels.

[0037] The horizontal cold chamber die casting machine is the basis of the HPDC technology. In the cold chamber process, the metal reservoir is separated from the injection system. The metal is filled into the steel cold chamber which is typically between 200 and 300°C. The typical production cycle in the HPDC consists of leading metal into the cold chamber, moving the plunger and rapidly filling the die which dissipates the latent heat. During solidification, the casting is pressurized hydraulically by the plunger to feed the solidification shrinkage. Locking forces up to 4000 tons are available to withstand the large pressures. The die is then opened and the cast product is ejected.

[0038] Hydraulic energy is provided by computerized systems that permit control of metal, position, velocity and plunger acceleration to optimize the flow and the pressure during filling and solidification. The die cavity may be evacuated to reduce air entrapment during die filling. Therefore, high integrity die casting can be produced by utilizing vacuum systems. Alternatively, SSM can be used to reduce turbulence. In conventional die casting, the expertise of the foundry worker is critical to the final cast product. Therefore, SSM takes the guess work out of casting and results in a consistently high quality cast product.

[0039] A short die filling time and thin walls result in high cooling rates. This promotes a fine grain size which provides decent mechanical properties. The alloy itself is also very important. The alloy characteristics must fulfill the necessary requirements of castability which involves higher fluidity, good feeding and low hot tearing technology.

[0040] HPDC also allows for rapid solidification and alloy flexibility in that the machines can accommodate hypoeutectic or hypereutectic alloys, those containing less than 12.7% silicon or more than 12.7% silicon, respectively. HPDC also allows for a greater number of cavities per die.

[0041] FIG. 2 is an illustration of a HPDC die casting machine having the in-situ slurry formation apparatus 10 incorporated therein. The HPDC casting cycle consists of a holding furnace 28 that retains the liquid metal to be cast. A ladle (not shown) takes the metal and pours it into the in-situ slurry formation apparatus 10, where the liquid metal transforms into the SSM state. The SSM metal then exits the in-situ slurry formation apparatus 10 into

a pour hole 34. A hydraulic system 30 then provides a shot cylinder 32 the ability to inject the SSM metal into a die cavity 36.

[0042] The cold chamber 38 holds the liquid metal in place. The cold chamber 38 in a HPDC machine is where the metal is poured in by the ladle from the furnace before the metal is injected into the die. The metal is transferred from the furnace into the in-situ slurry formation apparatus 10 and then the metal flows into the cold chamber 38. Once the metal is in the cold chamber, the metal will be injected into the die.

[0043] Die 40 are then moved forward by a platen 42 and the platen 42 is held in place by tie bars 44 while the metal is cast. The platen 42 reciprocating movement is controlled by clamping knuckles 46, closing and locking the die 40, maintaining adequate pressure, permitting the metal to solidify, opening the die 40 and ejecting the cast product. The product may then be appropriately finished or sprayed.

[0044] FIG. 3 is a detailed representation of the in-situ slurry formation apparatus 10 configured for the HPDC machine 48 of FIG. 2. In particular, the funnel block 12 may be disposed over an injection sleeve 50. Metal exiting the funnel 14 at the funnel exit 20 enters the injection sleeve 50 at the injection sleeve inlet 52 and exits the injection sleeve 50 at the injection sleeve outlet 54. The injection sleeve inlet 52 may be associated with the pour hole 34 of FIG. 2.

[0045] The temperature of the molten metal entering the in-situ slurry formation apparatus 10 should be above the liquidus temperature for the particular aluminum alloy in the furnace. For certain aluminum alloys, depending on the alloy chemistry, the metal temperature should be even higher than the liquidus to prevent sludge formation in the furnace. However, too much superheat (temperatures over the liquidus) allows for more hydrogen to enter the metal which leads to casting defects. The higher the superheat of the metal in the furnace, the more temperature the in-situ slurry formation apparatus 10 has to remove to get the metal in the SSM range. The metal temperature in the furnace needs to be as low as possible but still be above the liquidus temperature. The temperature must also prevent any sludge particles from forming in the particular alloy. Thus, the temperatures will vary with the particular alloy chemistry.

[0046] In-situ slurry formation apparatus 10 temperatures should be at a temperature that can be maintained at a steady state from cycle to cycle. This depends on the size of in-situ slurry formation apparatus 10 and the amount of metal being poured through the in-situ slurry formation apparatus 10. This temperature will also be kept as low as possible. However, the temperature should be high enough so the metal will not solidify inside the in-situ slurry formation apparatus 10. Therefore, the temperature range may be in the range of 150 degrees Fahrenheit to 500 degrees Fahrenheit. However, the ranges may vary based on the in-situ slurry formation apparatus 10 size, metal chemistry and metal quantity.

[0047] FIG. 4 is a representation of a Horizontal with Vertical Shot Components, (HVSC) die casting machine 56 having the in-situ slurry formation apparatus 10 incorporated therein. The liquid metal is contained in a holding furnace 58. A ladle (not shown) pours the liquid metal from the holding furnace 58 into the in-situ slurry formation apparatus 10. The liquid metal is transformed into SSM state in the in-situ slurry formation apparatus 10. Then, a shot cylinder 60 tilts towards the in-situ slurry formation apparatus 10 and the SSM metal enters the shot cylinder 60.

[0048] The shot cylinder 60 then tilts back to the original vertical position. The tilt-docking injection unit or shot cylinder 60 contains a separated shot sleeve 64 for cooling and transfer. A hydraulic system 62 then pushes the shot sleeve 64, enveloped by the shot cylinder 60, into the die cavity 66, and the shot sleeve 64 deposits the SSM metal. A platen 72 then moves die 68 and locks the die in place using tie bars 70. Clamping knuckles 74 allow the die 68 to open and close. Once the SSM metal is cast, the cast product is ejected when the platen 72 moves back. Thus, HVSC machines contain horizontal die clamping with a vertical, high pressure delivery system.

[0049] FIG. 5 is a detailed representation of the in-situ slurry formation apparatus 10 configured for the HVSC machine of FIG. 4. HVSC is a horizontal clamping vertical shot chamber machine. The sleeve is vertical at a 15-20 degree angle and it fills up the tube at an angle. The liquid metal is transferred and poured into the funnel 14 where the metal flows through the funnel 14 undergoing conduction and heat loss. The metal exiting the funnel 14 is at SSM state and is then injected into the die, forming a cast product.

[0050] The in-situ slurry formation apparatus 10 is disposed over the injection sleeve 64. The SSM metal exits the funnel block 12 at the funnel exit 20, into the injection sleeve inlet 78 and exits the injection sleeve 64 via the injection sleeve outlet 80. The injection sleeve 64 may be associated with the shot cylinder 60 of FIG. 4.

[0051] Although the in-situ-slurry formation apparatus 10 is shown with HPDC and HVSC machines, one skilled in the art will recognize that any casting machine in existence now or created later may easily be incorporated with the in-situ slurry formation apparatus 10, without being outside the scope of this invention.

[0052] FIG. 6 is an illustration of the microstructure obtained for a 356 alloy. FIG. 7 is an illustration of the microstructure obtained for a 206 alloy. A variety of metals and alloys may be used in the in-situ-slurry formation apparatus 10. However, the in-situ-slurry formation apparatus 10 may be particularly suitable for 356, 357, 206, 380, 383, 390 alloys, as well as ADC-12 and 7XX series alloys.

[0053] In addition to providing SSM slurry and to achieving the desired microstructure, the in-situ slurry formation apparatus 10 may also be used with liquid metal squeeze casting or conventional high pressure die casting. The in-situ slurry formation apparatus 10 re-

moves heat from the liquid metal as the metal flows through. This removal of heat lowers the temperature of the metal and reduces cycle time. The lower temperature of the metal permits it to solidify faster and increases the efficiency of the process. Thus, the in-situ slurry formation apparatus 10 may be used to provide SSM slurry or lower temperature liquid metal squeeze casting for a variety of applications.

[0054] The present invention, therefore, easily allows existing machinery to accommodate SSM without the need for costly capital equipment or additional space in the plants. The in-situ slurry formation apparatus 10 may be formed with a steel insert with copper and beryllium casings. In addition, it is highly wear resistant. The in-situ slurry formation apparatus 10 may also be fabricated from ANVILOY®, (Mallory Alloys Group, St. Albans, England) which is a highly conductive steel.

[0055] ANVILOY® is a tungsten based material made using high temperature powder metallurgy techniques. It was developed specifically for its high temperature strength and excellent thermal conductivity. It is used in place of lower conductivity high temperature tool steels. A benefit of ANVILOY® is its simplicity of tool manufacture i.e., no heat treatment, low erosion and excellent resistance to thermal cracking. This allows for ANVILOY® to replace H-13 steel. High thermal conductivity allows increased cooling rates in difficult to cool areas of a die casting and has the potential to increase production rates. ANVILOY® can be easily machined and can be repair welded.

[0056] Some of the benefits of ANVILOY® include minimal thermal fatigue, minimal soldering, low erosion, and accelerated cooling. ANVILOY® may be easily machined and worn parts are easy to remachine into smaller diameter core pins. ANVILOY® may be easily welded and repaired and requires no heat treatment before or after machining.

[0057] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

Claims

1. An apparatus for converting molten metal to semi-solid metal comprising:

a conduit having an inlet and an outlet to transport the molten metal; and
a temperature regulator disposed adjacent the

conduit to regulate the temperature of the molten metal; and
a housing surrounding the conduit and the temperature regulator.

2. The apparatus of claim 1, wherein the temperature regulator further comprises a heater, a cooler and a temperature sensor, operably coupled to a controller.
3. The apparatus of claim 1, wherein the temperature regulator further comprises a hot oil system and a temperature sensor operably coupled to a controller.
4. The apparatus of claim 3, wherein the hot oil system is configured to heat and cool the conduit.
5. The apparatus of claim 1, wherein the conduit has a funnel shape.
6. The apparatus of claim 5, wherein the funnel comprises a first end having a first diameter, a second end having a second diameter and a path disposed between the first and second ends, wherein the first diameter is larger than the second diameter, and wherein the path has a non-linear configuration.
7. The apparatus of claim 1, wherein the conduit has a length configured to cool molten metal to semi-solid metal.
8. The apparatus of claim 1, wherein the housing is configured to couple to a die casting machine.
9. The apparatus of claim 1, wherein the conduit further comprises a non-wetting coating on an inside surface of the conduit.
10. The apparatus of claim 9, wherein the non-wetting coating further comprises a tungsten thermal coating, a boron nitride coating or a ceramic coating.
11. The apparatus of claim 1, wherein the outlet is coupled to a die casting machine inlet.
12. The apparatus of claim 1, wherein the apparatus is configured to couple to a high pressure die casting (HPDC) machine.
13. The apparatus of claim 1, wherein the apparatus is configured to couple to a horizontal with vertical shot components (HVSC) die casting machine.
14. The apparatus of claim 1, wherein the apparatus is configured to convert molten metal 206, 356, 357, 380, 383, 390, ADC-12 and 7XX alloys to semi-solid metal.

15. The apparatus of claim 1, wherein the conduit further comprises a thermally conductive material.
16. The apparatus of claim 15, wherein the conduit further comprises a steel insert with copper and beryllium casings. 5
17. The apparatus of claim 15, wherein the conduit further comprises tungsten. 10
18. A method for converting molten metal to semi-solid metal comprising:
- coupling a conduit to a die casting machine, wherein the conduit comprises an inlet, an outlet and a body disposed between the inlet and the outlet; 15
- regulating the conduit's temperature; surrounding the conduit with a housing; 20
- inserting molten metal at the inlet; 20
- cooling the molten metal to semi-solid metal in the body; and
- expelling semi-solid metal from the outlet.
19. The method of claim 18, wherein the step of regulating the temperature of the conduit is done through a heater, a cooler and a temperature sensor operably coupled to a controller. 25
20. The method of claim 19, wherein the step of regulating the temperature of the conduit is done through a hot oil system and a temperature sensor operably coupled to a controller. 30
21. The method of claim 18, wherein the body has a non-linear configuration. 35
22. The method of claim 18, wherein the conduit comprises a thermally conductive material. 40
23. The method of claim 18, wherein the conduit comprises a non-wetting coating to prevent the oxidation of aluminum. 40
24. The method of claim 18, wherein the conduit has a funnel shape. 45
25. A system for converting molten metal to semi-solid metal comprising: 50
- means for coupling a conduit to a die casting machine, wherein the conduit comprises an inlet, an outlet and a body disposed between the inlet and the outlet; 50
- means for regulating the conduit's temperature; 55
- means for surrounding the conduit with a housing; and
- means for cooling the molten metal to semi-solid metal in the body.
26. The system of claim 25, wherein the means of regulating the temperature of the conduit is done through a heater, a cooler and a temperature sensor operably coupled to a controller.
27. The system of claim 25, wherein the step of regulating the temperature of the conduit is done through a hot oil system and a temperature sensor operably coupled to a controller.
28. The system of claim 25, wherein the body has a non-linear configuration.

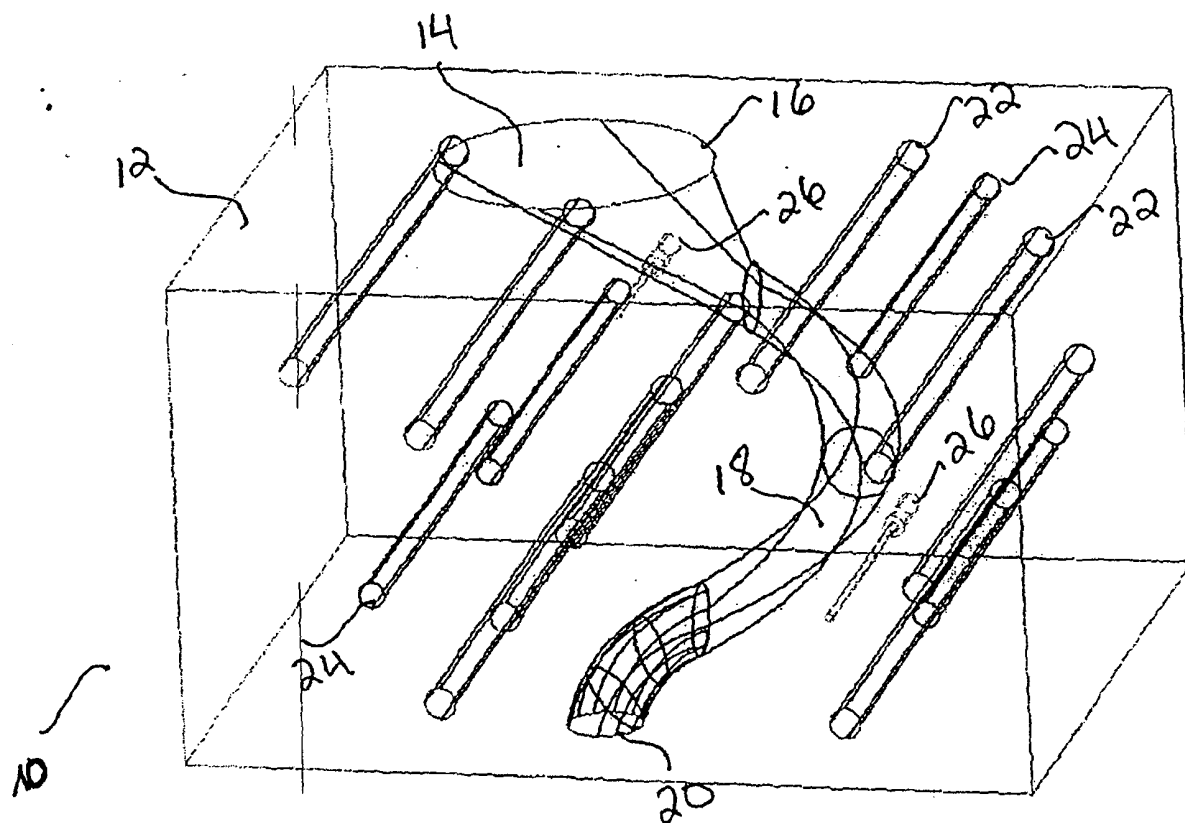


Fig. 1

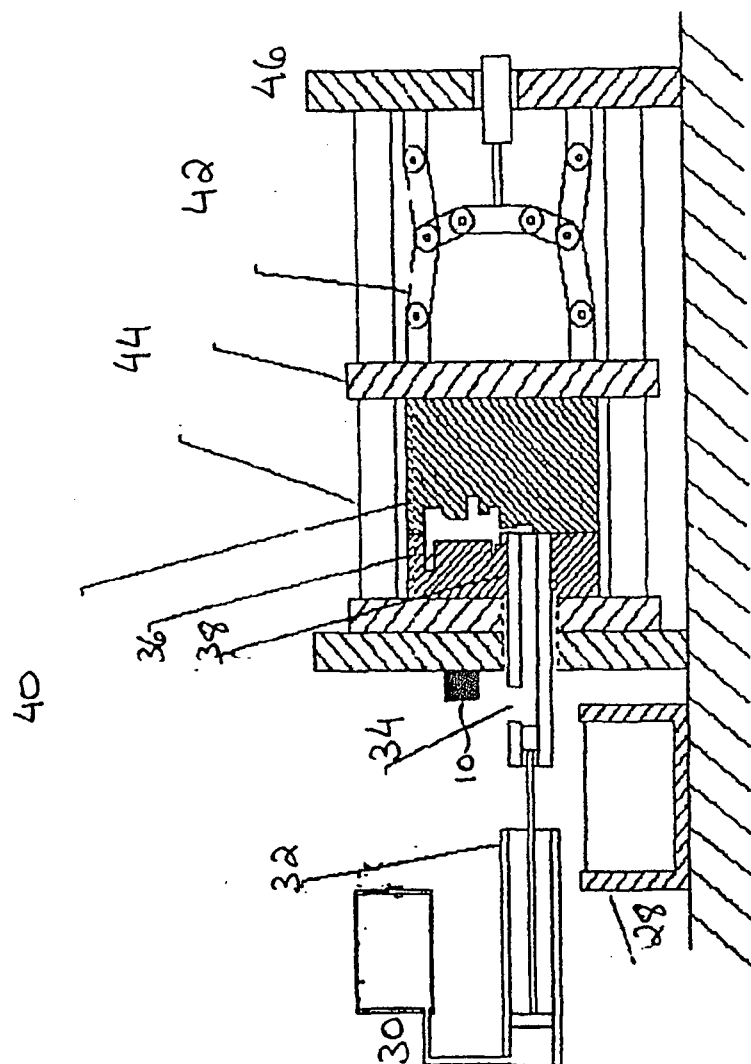


Fig. 2

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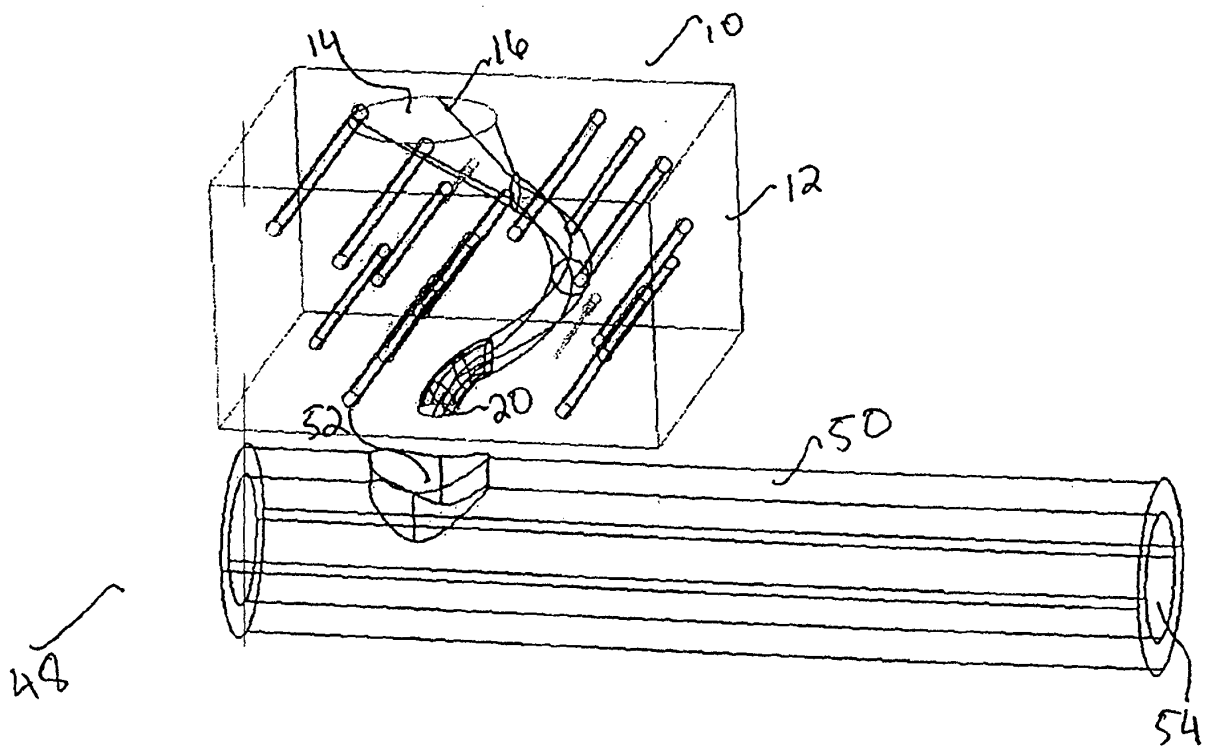
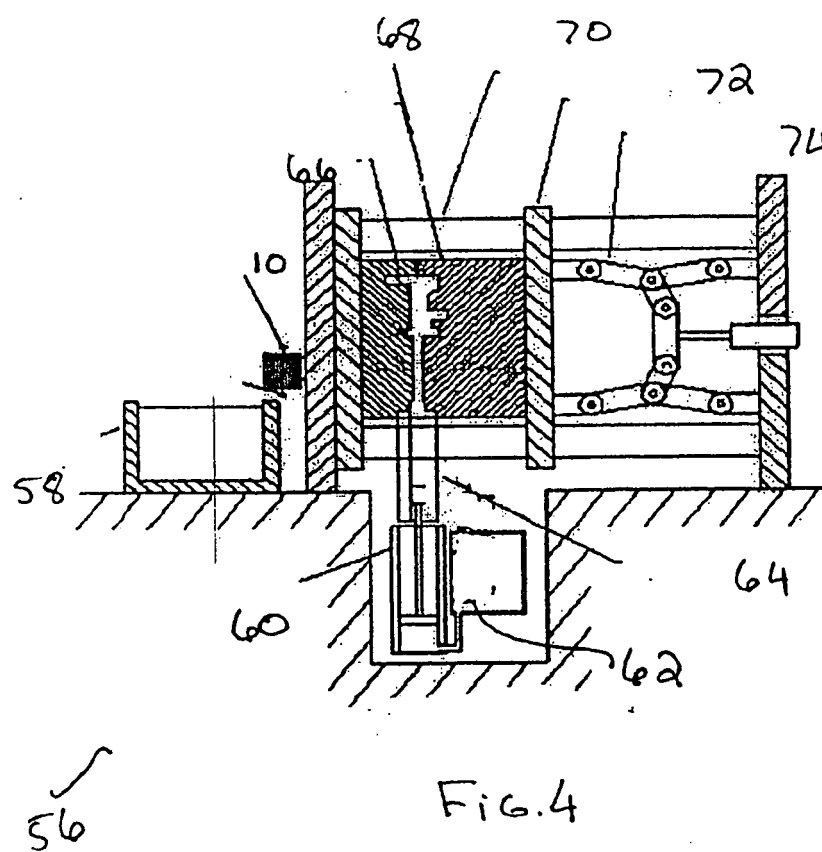


Fig. 3



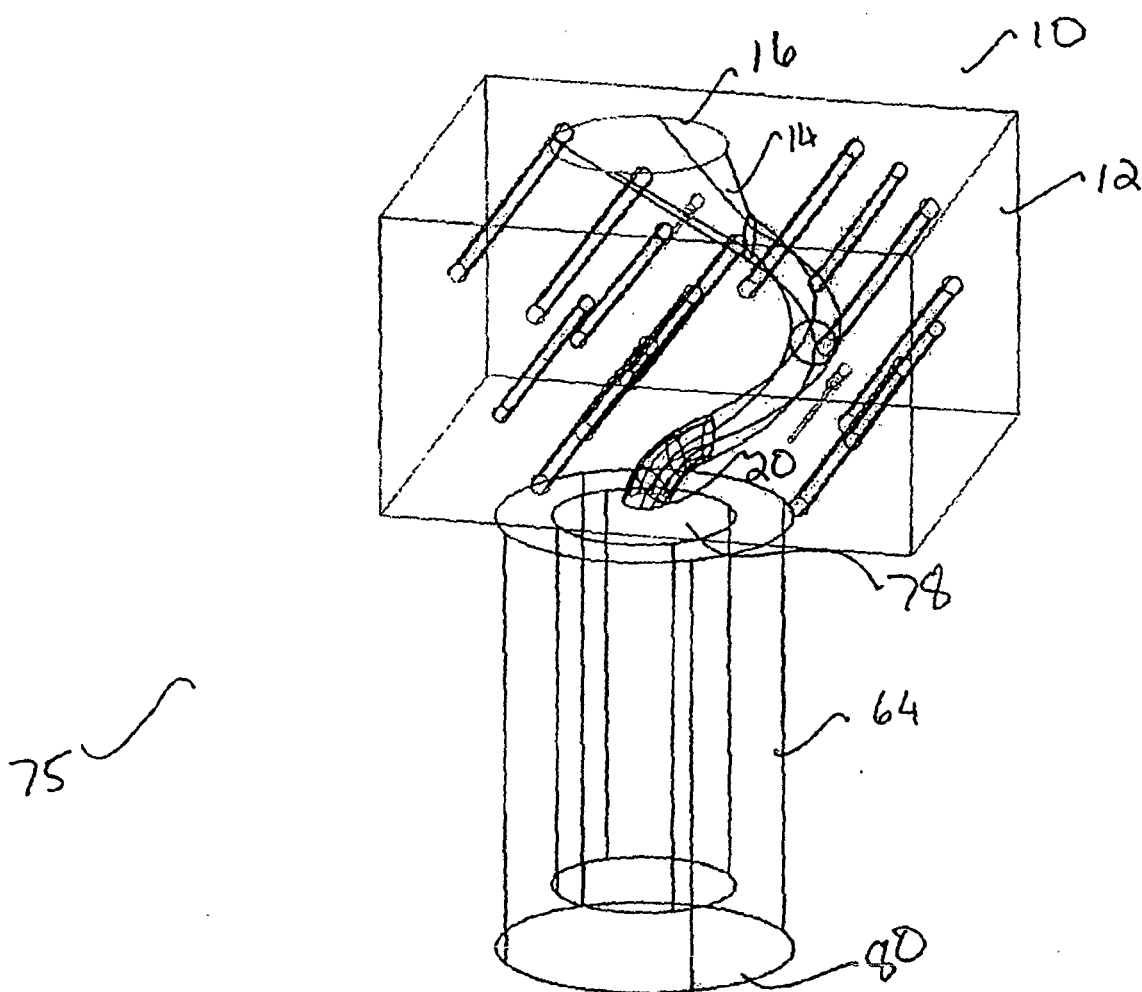


FIG. 5

FIG. 6
356 Alloy

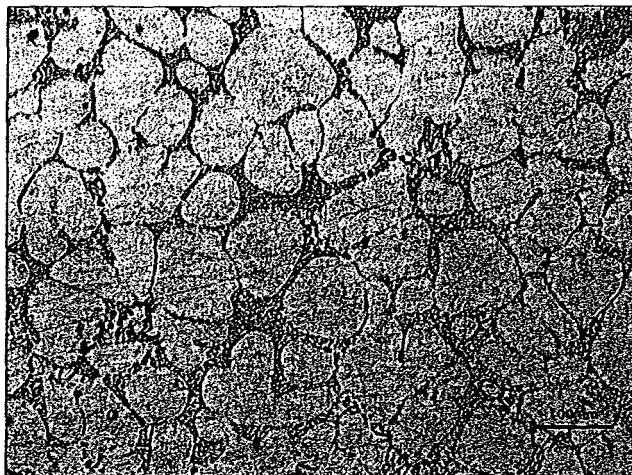
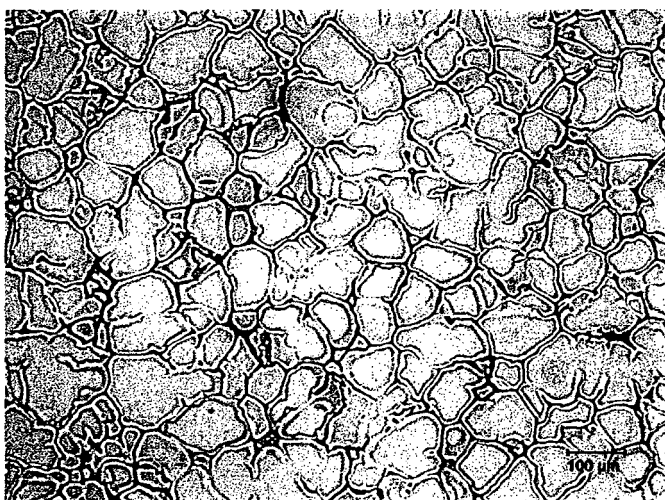


FIG. 7
206 Alloy



REFERENCES CITED IN THE DESCRIPTION

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