Apparatus for casting metallic materials, includes a processing device for preparing metallic material in free-flowing form and a storage container in communication with the processing device for receiving a continuous flow of prepared metallic material. An injection unit including a piston and cylinder arrangement is arranged separately from and connected to the storage container by a flow connection which includes a flow regulating device to control a flow therethrough. The storage container and the piston and cylinder arrangement are heated separately by a heating assembly, thereby ensuring short cycle times and establishment of great variability during a casting operation.
APPARATUS AND METHOD FOR CASTING METALLIC MATERIALS

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the priority of German Patent Application, Serial No. 101 57 349.9, filed Nov. 22, 2001, pursuant to 35 U.S.C. 119(a)-(d), the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention relates, in general, to an apparatus and method for casting metallic materials.

[0003] U.S. Pat. No. 5,881,796 issued on Mar. 16, 1999 describes an apparatus and method for transferring molten material into a heatable container in which the molten material is cooled down to a temperature between solidus and liquidus. An agitating device is provided to maintain the material in a free-flowing state in this temperature range and to provide a homogeneous temperature distribution as well as to shear dendrites that tend to form during the cool down process.

[0004] As a result of the cyclic supply of molten material to the storage container, temperature fluctuations are encountered which can be kept sufficiently small only when the existing and remaining volume of metallic material is sufficiently large. Therefore, the cyclic supplies, which correspond to a shot, should be limited to smaller than 10% of the volume in the storage container or, vice versa, the volume in the storage containers should be selected sufficiently large. At greater shots, this approach is problematic and limits also the flexibility as far as construction of the casting device is concerned.

[0005] As the temperature during processing of metals is necessarily fairly high, and this is true also during casting of light metals such as magnesium and aluminum, the demands on the components of a casting device are high and together with the relatively high shot pose particular problems.

[0006] Conventional apparatuses suffer also shortcomings because their processing units for preparing metallic material are operated in dependence on subsequent processing steps, so that the theoretically possible capability of the processing units cannot be fully exploited. In order to still attain relatively short cycle times, proposals have been made to oversize the processing unit in relation to the drawn shot in order to keep the processing times as short as possible. This approach, however, is inefficient and costly.

[0007] It would therefore be desirable and advantageous to provide an improved apparatus and method for casting metallic material to obviate prior art shortcomings and to accomplish a great versatility in conjunction with a temperature control during the casting process.

SUMMARY OF THE INVENTION

[0008] According to one aspect of the present invention, an apparatus for casting metallic materials includes a processing device for preparing metallic material in free-flowing form, a storage container in communication with the processing device for receiving a continuous flow of prepared metallic material, an injection unit including a piston and cylinder arrangement arranged separately from the storage container, a flow connection linking the storage container with the injection unit and including a flow regulating device to close and open the flow connection, and a heating assembly including a heating device for the storage container and a heating device for the piston and cylinder arrangement.

[0009] The present invention resolves prior art problems by providing a storage container to receive prepared metallic material from the processing unit to thereby allow a continuous operation of the processing unit. Thus, the processing unit can be operated at maximum efficiency. By separating the injection unit from the storage container and connecting the injection unit to the storage container via a flow connection, which can be opened or closed by a suitable valve element to regulate the flow of metallic material, forces applied in the system during the injection operation are restricted to the injection unit. Therefore, provision of enough mechanical strength is an issue only for the injection unit. As the flow connection between the injection unit and the storage container can be cut, the risk of a return flow of metallic material from the injection unit back to the storage container is eliminated and pressure is able to build up in the injection unit.

[0010] The apparatus according to the present invention avoids the integration of numerous functions in a single assembly which is subject to great stress. As a result, there is no need to provide large components of expensive high-temperature materials, and the materials for the casting apparatus can be selected to best suit the individual components of the apparatus.

[0011] The functional separation of components of the casting apparatus results not only in a greater flexibility when dimensioning the apparatus but also in less wear because there is no need to provide a back flow valve, as conventionally used in the injection molding field and because moving masses can be minimized. In addition, maintenance or repair works can be carried out, without requiring complicated dismantling of the entire processing and injection aggregate. The casting apparatus according to the present invention can easily be conformed to different requirements of the materials being processed and to short cycle times through parallel processing during the entire cycle. Moreover, the injection unit can easily be adjusted to desired injection outputs, for example, through appropriate selection of the piston size of the piston and cylinder arrangement. This can be realized regardless of the dimensions of other apparatus components.

[0012] According to another feature of the present invention, the metallic material can be processed in the processing device at a temperature above the liquidus temperature to effect a homogenous, completely liquid phase, or to at least prepare the metallic material in liquid form during a predetermined period and then to optionally return it to a state between liquidus and solidus in which the material exhibits thixotropic characteristics. This is advantageous because the starting material has been completely melted so that the original condition, i.e. the texture of the starting material becomes secondary for the properties of the end product.

[0013] As an alternative, the starting material may be prepared by the processing unit directly in thixotropic form, without being completely liquefied beforehand. This process
is cost-effective because input of energy is required only for transformation of the material into the thixotropic state. Moreover, the thermal strain on the construction materials of the apparatus is minimized.

[0014] As both these variations have advantages, the processing device of the casting apparatus according to the invention can be so configured as to be able to realize either one of the temperature control systems or type of processing.

[0015] According to another feature of the present invention, there is provided an agitating device for stirring the metallic material in the storage container. The starting operation results in a forced convection in the storage container and thus to a more even temperature distribution even when the storage volume is slightly greater and the retention time of the prepared metallic material in the storage container is longer. In other words, the shot in relation to the volume of the storage container is fairly small. Examples of an agitating device include a mechanical agitating device or an electromagnetic agitating device. The provision of an electromagnetic agitating device enables a defined heat introduction into the prepared metallic material in the storage container so that the need for a separate heating device for maintaining the metallic material at a constant temperature may be eliminated.

[0016] According to another feature of the present invention, there may be provided a static mixer disposed in the flow connection between the storage container and the injection unit. The static mixer provides a sufficient removal of dendritic structures during transfer of the prepared metallic material from the storage container to the injection unit. Of course, also in this case, a combination with a device for generating forced convection is possible in the volume of the storage container and, indeed, also desirable, in particular when the volumes of metallic material have comparably long mean retention times in the storage container.

[0017] The injection unit, designed separately from the storage container, includes a piston and cylinder arrangement arranged outside the volume of the storage container. Of course, it is not necessarily required to prevent a direct contact between the piston and cylinder arrangement and the storage container; rather there may be situations in which the heating device of the storage container should be exploited for heating the injection unit and its piston and cylinder arrangement. In this case, the storage container and the piston and cylinder arrangement can be combined in a quasi common block. Even though, the piston and cylinder arrangement will still have a separate heating device.

[0018] Versatility is, however, enhanced when the injection unit, including the piston and cylinder arrangement, and the storage container are structurally completely separate from one another and equipped with separate heating devices. In this case, it becomes easier to control the temperature of the piston and cylinder arrangement in order to suit the casting apparatus to the molded product being produced by adjusting the viscosity of the injected metallic material to be prepared to the geometric configurations of the product being produced.

[0019] A casting apparatus according to the present invention enables the provision of a continuously operating processing device. In this case, the storage container is so configured as to permit a variable fill level of prepared metallic material. Suitably, a remaining volume in the storage container above the actual fill level of prepared metallic material is filled with an inert gas.

[0020] According to another feature of the present invention, the flow connection may enter the storage container at an area below a minimum fill level of processed metallic material. In this way, freshly prepared metallic material incoming from the processing device is prevented from contacting the gas volume above the fill level of the storage container and thus prevented from contacting a gas atmosphere, which may be contaminated with oxidizing agents. Suitably, the inert gas volume has a pressure which is maintained at a substantially constant pressure value. This can be realized by incorporating any suitable pressure control system known to a person skilled in the art. The pressure value may hereby also correspond to a pressure below atmospheric so that a mass of prepared metallic material accumulated in the storage container can be degassed.

[0021] Suitably, the gas volume in the storage container may be part of a through-flow system of the casting apparatus so that a continuous exchange of inert gas above the fill level in the storage container can take place. In this way, especially outgassing metallic materials can be freed from these contaminations. For cost reasons, the gas volume may be part of a closed through-flow system in which in particular in conjunction with outgassing starting materials, a cleaning device can be integrated for the inert gas.

[0022] According to another feature of the present invention, the piston and cylinder arrangement may have a cylinder in a substantially vertical disposition. In other words, the axial direction of the cylinder of the piston and cylinder arrangement is vertical. As the piston of the piston and cylinder arrangement is of solid configuration for the casting operation and in view of the hereby resultant weight, the piston can normally not be pushed back by the fill level in the storage container from one end position, in which the injection volume is minimal, to a position, in which the injection volume corresponds to the shot volume. Therefore, the piston is preferably actively controlled for return to its shot position.

[0023] Alternatively, the cylinder of the piston and cylinder arrangement may also be arranged in a substantially horizontal disposition.

[0024] Forces applied during the shot in the area of the piston and cylinder arrangement may be exploited to provide an additional sealing action between the piston and the cylinder wall. Hereby, the piston has a circumference, which may be formed with at least one groove for receiving a sealing ring, and has an end face, which may be formed with an orifice connected to the groove by at least one channel at the circumference of the piston. As the pressure increases on the end face of the piston during shot, prepared metallic material migrates into the orifice and flows via the channel into the annular groove on the circumferential area of the piston to push the sealing ring outwards against the inner wall surface of the cylinder. As a consequence, as the shot pressure increases, so does the pressure by which the sealing ring is pressed against the inner wall surface of the cylinder to thereby effect the sealing effect of the sealing ring.

[0025] The controllable flow connection between the storage container and the injection unit may include a check
valve. As an alternative, the apparatus may also include here an actively closing element, such as, e.g., a gate construction.

[0026] According to another feature of the present invention, the processing device may include an extruder. The extruder defines a longitudinal axis which may be inclined downwards in a transport direction of the prepared metallic material relative to a horizontal at an angle of 0° to 45°, and may have a discharge end for directly introducing the metallic material into the storage container at a level below a minimum fill level. Alternatively, the extruder may have a discharge end for introducing the metallic material into the storage container at a level above a maximum fill level. In this case, melt is introduced via a baffle, extending in the storage container, below the level of the minimum fill level of the storage container. This has the advantage that the maximum admissible fill level in the storage container is still below the extruder discharge end so that a backup flow to the extruder screw can no longer occur.

[0027] The processing device may include a feed unit for supply of metallic starting material into the extruder in controlled doses. Examples of such a feed unit include a screw-type metering device or a rotary feeder. Suitably, the feed unit supplies a reduced amount of the starting material to the extruder. In this way, bridge formation is avoided and the flow throughput, i.e. shot per cycle unit and shearing rate (rotation speed of the screw) are independent from one another.

[0028] According to another feature of the present invention, the starting material may be a solid, wherein the heating assembly includes a further heating device for the feed unit for pre-heating the solid before reaching the extruder.

[0029] According to another aspect of the present invention, a method of casting a metallic material, includes the steps of continuously preparing metallic material in free-flowing form for supply to a storage container with constant volume and variable fill level, periodically transferring the metallic material into an injection unit with a piston and cylinder arrangement, and injecting the metallic material by the injecting unit into a molding tool, wherein the piston and cylinder arrangement of the injection unit and the storage container are heated separately and independently from one another.

[0030] A method according to the invention is also characterized by the functional separation of components to attain the afore-stated advantages.

[0031] According to one variation of the method according to the invention, a solid starting material is heated to a temperature above the liquids temperature to provide a homogeneous, completely liquid phase, and subsequently cooled down to a temperature above a solidus temperature but not exceeding the liquidus temperature so that the thus-prepared metallic material has liquid and solid phases for subsequent transfer to the storage container. The prepared metallic material is then further processed in this semi-solid, thixotropic state, i.e. transferred to the injection unit for subsequent injection into the molding tool.

[0032] This process sequence is advantageous because the texture of the original metallic starting material is no longer an issue as a consequence of the complete liquefaction so that the finished product exhibits a homogeneous structure. This advantage, is, however, accompanied by a higher energy consumption and greater heat-up rate or by a more complex processing device. Also the construction materials are exposed to greater stress and the sealing technique becomes more complex. In addition, gas solubility and oxidation may be increased.

[0033] As an alternative to this process sequence, it is also possible to directly heat the solid starting material to a temperature between solidus and liquidus, i.e. the originally solid material is directly transformed into a semi-solid state in which both liquid and solid phases are present, without preceding transformation into a homogeneous, completely liquid phase through heating above liquidus. In this way, energy consumption is decreased, as are heat-up rates, and the construction material is exposed to less stress, while the sealing technique becomes also less complex and gas solubility and tendency for oxidation is reduced.

[0034] According to another feature of the present invention, the prepared metallic material in the storage container may be exposed to a shearing action to remove forming dendritic structures.

[0035] Suitably, a temperature control is implemented which is separate for the storage container, i.e. the material in the storage container, on the one hand, and the material in the injection unit, on the other hand, in order to provide maximum flexibility. This flexibility of the temperature control is desirable because the viscosity of the prepared metallic material is greatly dependent on the temperature, i.e. ultimately on the solid fraction in the semi-solid material. Different viscosities of the prepared material may be a desirable in dependence on the component geometry and the resultant flow conditions during the injection process.

[0036] According to another feature of the present invention, the prepared metallic material in the storage container may be maintained under an inert gas volume. In this way, the prepared metallic material is protected against oxidation during its retention time in the storage container.

[0037] According to another feature of the present invention, the piston of the piston and cylinder arrangement may be actively moved independently on the transfer of metallic material into the injection unit so that the prepared metallic material can be transferred from the storage container actively into the injection unit, without reliance on gravitational effects. In this way, metering of the required shot is facilitated.

[0038] According to another feature of the present invention, the solid starting material may be pre-heated suitably under an inert gas atmosphere, before being transformed into a semi-solid state or homogeneously completely liquefied. In this way, the heat-up rate within the processing device can be lowered or, an extruder, provided in the processing device, can be configured of shorter dimension.

**BRIEF DESCRIPTION OF THE DRAWING**

[0039] Other features and advantages of the present invention will be more readily apparent upon reading the following description of currently preferred exemplified embodiments of the invention with reference to the accompanying drawing, in which:

[0040] Fig. 1 is a schematic illustration of a first embodiment of a casting apparatus according to the present invention;
FIG. 2 is a detailed view of the casting apparatus of FIG. 1 with a modified flow connection between storage container and injection unit;

FIG. 3 is a schematic illustration of a second embodiment of a casting apparatus according to the present invention;

FIG. 3a is a detailed cutaway plan view of the casting apparatus of FIG. 3;

FIG. 4 is a schematic illustration of a third embodiment of a casting apparatus according to the present invention;

FIG. 5 is a schematic illustration of an injection unit for use in a casting apparatus according to the present invention;

FIG. 6 is a schematic illustration of a fourth embodiment of a casting apparatus according to the present invention;

FIG. 7 is a graphical illustration of a temperature/time diagram according to the invention, showing the relation between temperature and time for two process variations.

**DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS**

Throughout all the Figures, same or corresponding elements are generally indicated by the same reference numerals. These depicted embodiments are to be understood as illustrative of the invention and not as limiting in any way.

Turning now to the drawings, and in particular to FIG. 1, there is shown a schematic illustration of a first embodiment of a casting apparatus according to the present invention, generally designated by reference numeral 10. The casting apparatus 10 includes a processing device 12 which receives solid metallic material 16 through a funnel-shaped feed unit 14 and cooperates with a storage container 18. Provided downstream of the storage container 18, the casting apparatus 10 includes an injection unit 20 and an injection mold 22.

The feed unit 14 is equipped with a heating device 24 for pre-heating the solid material 16, for example metallic granulate, which thus enters the processing device 12 at elevated temperature. The processing device 12 is implemented here by way of example in the form of an extruder having an extruder barrel 28 accommodating an extruder screw 26 which is suitably operated by a not shown drive unit. The extruder screw 26 draws solid metallic material 16 from the feed unit 14 for transport in the direction towards a discharge nozzle 29 of the extruder. A heating device 30 is arranged along the transport path of the metallic material 16 to provide the required heat introduction so that the metallic material 16 is, at least partially, melted and transformed into a free-flowing or liquid, optionally thixotropic state in dependence on the respectively applied temperature, thereby producing a prepared metallic material 34. The temperature of the metallic material 16 should be at all times above solidus, oftentimes in the range between solidus and liquidus, i.e. in a range in which two phases, namely a solid phase and a liquid phase, of the metallic material 16 are present. The temperature of the metallic material may also be below liquidus.

The extruder of the processing device 12 terminates with a discharge nozzle 29 in the storage container 18 which is also provided with a heating device 30 for keeping the prepared metallic material 34 in the storage container 18 at the desired temperature for maintaining the semi-solid thixotropic state. Dendritic structures, which tend to form during the retention time of the metallic material 34 in the storage container 18, are reduced by an agitating device 36 which forces a convection in the prepared metallic material 34 and shears the dendrites to provide more globularous particles and thus to maintain the prepared metallic material 34 in free-flowing form.

A gas volume 38, for example inert gas, is provided above the fill level of the prepared metallic material 34 which is introduced into the storage container 18 at a location below a minimum fill level of the storage container 18, as shown in FIG. 1, so as to be prevented from contacting the gas atmosphere. Suitably, a baffle 31 is hereby attached interiorly of the storage container 18 and suitably attached to an inside wall of the storage container 18. The fill level of prepared metallic material 34 in the storage container 18 is variable between a minimum fill level and a maximum fill level so that the gas volume 38 is variable accordingly.

The storage container 18 is connected to the injection unit 20 by a flow connection 40 through which the prepared metallic material 34 is transferred from the storage container 18 to the injection unit 20. The injection unit 20 includes a piston and cylinder unit 42 and a heating device 33. The flow connection 40 includes a flow regulating device 44, e.g., a valve for regulating a flow of prepared metallic material 34 between the storage container 18 and the injection unit 20 to thereby enable a pressure buildup during delivery of a shot to the injection mold 22 or during the actual molding process. By cutting the flow through the flow connection 40, material is prevented from flowing back to the storage container 18.

Referring to FIG. 2, there is shown a detailed view of a modified flow connection 40 between the storage container 18 and the injection unit 20 of the casting apparatus 10. Parts corresponding with those in FIG. 1 are denoted by identical reference numerals and not explained again. The flow connection 40 includes a section 46 in which a static mixer 48 is accommodated. The static mixer 48 is configured to provide a sufficient convection in the free-flowing metallic material 34 to reduce potentially existing dendrites and maintain the metallic material 34 in the free-flowing state for subsequent transfer to the injection unit 20.

In the event, the retention time of the prepared metallic material 34 in the storage container 18 is short enough and/or the thermal conditions in the storage container 18 are beneficial, the presence of the static mixer 48 in the flow connection 40 may make it possible to omit the provision of the agitating device 36 in the storage container 18 altogether.

FIG. 3 shows a schematic illustration of a second embodiment of a casting apparatus according to the present invention, generally designated by reference numeral 10a. In the following description, parts corresponding with those in FIG. 1 will be identified by corresponding reference numerals followed by an “a”. The processing device 12a is shown here only schematically by a block and may be configured
in a same way as the processing device 12 of the casting apparatus 10 for receiving solid metallic material from a feed unit (not shown). Prepared free-flowing metallic material is introduced from the processing device 12a into a storage container 18a for receiving the prepared metallic material 34 in a variable volume. Above the level of prepared metallic material 34 is a gas volume 38 whose volume varies in accordance with variations in volume of prepared metallic material 34 in the storage container 18a so that the sum of the volume of prepared metallic material 34 and the gas volume 38 remains constant.

[0057] The storage container 18a supports about its perimeter a heating device 32a in the form of an electric heating spiral and, moreover, an electromagnetic agitating device 56 for generating an electromagnetic field in the volume of the prepared metallic material 34 in order to apply a forced convection. This forced convection is sufficient to reduce dendrites, potentially forming in the free-flowing prepared metallic material, into more globuliferous particle shapes. The prepared metallic material 34 is transferred from the storage container 18a via a flow connection 40a to the injection unit 20 which may be configured in a same way as the injection unit 20 of the casting apparatus 10. A flow regulating device 44a opens and closes the passage through the flow connection 40a. The free-flowing metallic material 34 is injected by the injection unit 20a via a channel 64 to the cavity 68 of casting mold 22a.

[0058] FIG. 3a is a detailed cutaway plan view of the casting apparatus 10a and shows a more detailed illustration of the flow regulating device 44a which is configured here in the form of a check valve disposed in the flow connection 40a between the storage container 18a and the injection unit 20a. The provision of the check valve is by example only. Of course, the flow regulating device 44a may also be implemented in the form of a rotary slide valve in order to prevent a back flow of metallic material into the storage container 18a during the injection operation.

[0059] Turning now to FIG. 4, there is shown a schematic illustration of another embodiment of a casting apparatus according to the present invention, generally designated by reference numeral 10b. In the following description, parts corresponding with those in FIG. 1 will be identified by corresponding reference numerals followed by a “b”. The processing device 12b receives solid metallic material via the feed unit 14b for transforming the metallic material into a free-flowing form. The prepared metallic material is then transferred to the storage container 18b in which an agitating device 36b is arranged for generating a forced convection of the storage metallic free-flowing material. Construction and operation of the processing device 12b as well as the storage container 18b with agitating device 36b correspond to the embodiment of FIG. 1.

[0060] In the embodiment of FIG. 4, provision is made for a flow connection 40b which is situated at the bottom area of the storage container 18b for transfer of prepared metallic material from the storage container 18b via a flow regulating device 44b to the injection unit 20b which is of same construction as the injection unit of FIG. 1. As a result, the injection unit 20b is arranged in horizontal disposition in contrast to the vertical disposition of the injection unit 20 in FIG. 1. Thus, the piston of the piston and cylinder arrangement 42b is moved in horizontal direction as opposed to the vertical movement of the piston of the piston and cylinder arrangement 42 in FIG. 1. Cooperating with the injection unit 20b is again a casting mold 22b with cavity 68.

[0061] FIG. 5 is a schematic detailed view of injection unit 20 for use in a casting apparatus as shown in FIGS. 1 and 4. The injection unit 20 includes an injection cylinder 92 and injection piston 95 whose piston rod 96 moves the piston 95 back and forth in vertical direction. The piston 95 is formed on one end face 98 with an orifice 100 for communication with a traverse bore 102 in the piston 95. The traverse bore 102 extends diagonally through the symmetry axis of the piston 95 and terminates on each end in an annular groove 104 at an outer surface of the piston 95. Arranged in the annular groove 104 of the piston 95 is a sealing ring 108 which, together with further sealing rings 110, 112, provides a sealing of an injection volume 114. When the piston 95 is moved downwards during the injection process, free-flowing metallic material is forced via the orifice 100 into the traverse bore 102 and from there to the annular groove 104 on the outer circumference of the piston 95. As a consequence of the pressure buildup in the injection volume 114, the sealing ring 108, received in the annular groove 104, is pressed outwards against the inside wall surface of the cylinder 92 to reinforce the sealing action.

[0062] Referring now to FIG. 6, there is shown a schematic illustration of another embodiment of a casting apparatus according to the present invention, generally designated by reference numeral 10c. In the following description, parts corresponding with those in FIG. 1 will be identified by corresponding reference numerals followed by a “c”. In this embodiment provision is made for an inert gas system 122 and for a processing device 12c, which resembles a pot-like melting furnace, to receive solid metallic material and to heat the metallic material to a temperature above solids. Extending approximately diagonally to the volume of the processing device 12c is the shaft of an agitating device 126 with agitating elements 136 for thoroughly mixing the metallic material in the processing device 12c. The processing device 12c is heated by a heating device 30c, which is arranged at the bottom zone and sidewalls of the processing device 12c.

[0063] Arranged in the bottom zone of the processing device 12c is an opening 13 for discharge of prepared metallic material via a connection line 130 to the storage container 18 in which the agitating device 36 is accommodated to reduce forming dendritic structures. In the non-limiting example of FIG. 6, the shaft of the agitating device 126 extends into and through the connection line 130 and supports helical projections 128 along the portion traversing the connection line 130 so as to provide a defined supply of prepared free-flowing metallic material to the storage container 18. At the same time, the helical projections 128 prevent a transfer of solid, not yet processed, metallic material parts from the processing unit 12c into the storage container 18. In addition, these functional elements of the agitating device 126 reduce possibly forming dendritic structures, in the event the free-flowing metallic material is maintained at a temperature between liquidus and solidus and to stabilize the solid phase in the form of more globuliferous particles in the metal melt. The connection line 130 includes a separate heating device 134 so as to be able to change the temperature upwards or downwards during trans-
The prepared metallic material is stored in the storage container 18 for subsequent transfer to the injection unit 20 via flow connection 40. The agitating device 36 in the storage container 18 is of the mechanical type, although an electromagnetic agitating device may be used as well, as described in FIG. 3. Also in this embodiment, the storage container 18 includes a separate heating device 32.

Metallic material enters the injection unit 20 via the flow connection 40 whereby valve 44, e.g. a check valve or a slide valve, opens and closes the flow connection 40 to thereby enable a pressure-proof separation between the volume of the storage container 32 and the volume of the injection unit 20 during the injection process. The injection unit 20 is hereby also provided with a separate heating device 33 to permit a reconditioning of the prepared molten or free-flowing metallic material before the injection process.

At the high temperature required for melting the metallic material, the metallic material is normally extremely reactive so that the provision of an inert gas atmosphere is desirable in various components of the injection casting apparatus 10c. The inert gas system 122 includes one or more inert gas sources 146 which are connected via conduits 148, 149, 150 to admit inert gas to the respective components of the casting apparatus 10c. Conduit 149 directs inert gas to a surrounding area of the processing device 12c to prevent contact with the ambient atmosphere and to thereby prevent the formation of, for example, oxidizing material that may adversely affect the final product. Conduit 148 directs inert gas to the volume in the storage container 18 above the fill level of the free-flowing metallic material to prevent the formation of oxidizing compositions as well. Conduit 150 directs inert gas to the outlet side of the injection unit 20 to prevent ingress of oxygen from the ambient atmosphere around the injection unit 20 during cycles between the respective injection process.

Of course, the inert gas system as described in conjunction with FIG. 6 is certainly applicable for all embodiments described herein.

The inert gas system may also be configured as a through-flow system whereby, for example, inert gas is supplied from an inert gas source to the gas compartment of the processing device for further transfer to the gas compartment of the storage container. Small fractions of introduced inert gas can escape from the gas volume of the processing device in opposite transport direction of the solid metallic material so that the ingress of atmospheric oxygen through the solid material is minimized.

Referring now to FIG. 7, there is shown a graphical illustration of a temperature/time diagram according to the invention, showing the relation between temperature and time for two process variations. In a first variation, indicated by graph (1), the temperature of the metallic starting material is initially raised above liquidus and then lowered to a range between liquidus and solidus. In this way, the presence of solid components with original texture of the starting material in the finished product is avoided. As a result, the finished product has a maximum homogeneity in texture.

In a second variation, indicated by graph (2), the metallic starting material is heated to a temperature at which the material is injected into the cavity of the molding tool. In this way, heat energy is saved and corrosion of surfaces contacting the metallic material is minimized.

While the invention has been illustrated and described in connection with currently preferred embodiments shown and described in detail, it is not intended to be limited to the details shown since various modifications and structural changes may be made without departing in any way from the spirit of the present invention. The embodiments were chosen and described in order to best explain the principles of the invention and practical application to thereby enable a person skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. Apparatus for casting metallic materials, comprising:
   a. a processing device for preparing metallic material in free-flowing form;
   b. a storage container in communication with the processing device for receiving a continuous flow of prepared metallic material;
   c. an injection unit including a piston and cylinder arrangement arranged separately from the storage container;
   d. a flow connection for linking the storage container with the injection unit, said flow connection having a flow regulating device to close and open the flow connection; and
   e. a heating assembly including a first heating device for the storage container and a second heating device for the piston and cylinder arrangement.

2. The apparatus of claim 1, wherein the metallic material is processed in the processing device at a temperature above a liquidus temperature to effect a homogenous, completely liquid phase.

3. The apparatus of claim 1, wherein the metallic material is processed in the processing device at a temperature above a solidus temperature but not exceeding a liquidus temperature so as to realize a material with liquid and solid phases.

4. The apparatus of claim 1, and further comprising an agitating device for stirring the metallic material in the storage container.

5. The apparatus of claim 4, wherein the agitating device is a mechanical agitating device.

6. The apparatus of claim 4, wherein the agitating device is an electromagnetic agitating device.

7. The apparatus of claim 4, and further comprising a static mixer disposed in the flow connection between the storage container and the injection unit.

8. The apparatus of claim 1, wherein the storage container is constructed for operation with a variable fill level of processed metallic material.

9. The apparatus of claim 8, wherein the storage container includes a variable gas volume above the fill level of prepared metallic material.

10. The apparatus of claim 8, wherein the flow connection enters the storage container at an area below a minimum fill level of prepared metallic material.
11. The apparatus of claim 8, wherein the flow connection enters the storage container at an area above a maximum fill level of prepared metallic material.

12. The apparatus of claim 8, wherein the gas volume has a pressure which is controlled at a substantially constant pressure value.

13. The apparatus of claim 8, wherein the gas volume includes inert gas.

14. The apparatus of claim 8, wherein the volume is part of a through-flow system.

15. The apparatus of claim 14, wherein the gas volume is part of a closed through-flow system.

16. The apparatus of claim 1, wherein the piston and cylinder arrangement has a cylinder in a substantially vertical disposition.

17. The apparatus of claim 1, wherein the piston and cylinder arrangement includes a cylinder in a substantially horizontal disposition.

18. The apparatus of claim 1, wherein the piston and cylinder arrangement includes a piston having a circumference, which is formed with at least one groove, and a sealing ring received in the groove, said piston having an end face formed with an orifice connected to the groove by at least one channel at the circumference of the piston.

19. The apparatus of claim 1, wherein the flow regulating device includes a check valve disposed in the flow connection between the storage container and the injection unit.

20. The apparatus of claim 1, wherein the flow regulating device includes an actively closeable valve disposed in the flow connection between the storage container and the injection unit.

21. The apparatus of claim 1, wherein the processing device includes an extruder.

22. The apparatus of claim 21, wherein the extruder moves the metallic material in a transport direction and defines a longitudinal axis which is inclined downwards in the transport direction relative to a horizontal at an angle of 0° to 45°, said extruder having a discharge end for directly introducing the metallic material into the storage container at a level below a minimum fill level of the prepared metallic material.

23. The apparatus of claim 21, wherein the extruder has a discharge end for introducing the metallic material into the storage container at a level above a maximum fill level of the prepared metallic material.

24. The apparatus of claim 21, wherein the processing device includes a feed unit for supply of metallic starting material into the extruder in controlled doses.

25. The apparatus of claim 24, wherein the feed unit is operated to supply a reduced amount of starting material to the extruder.

26. The apparatus of claim 24, wherein the starting material is a solid material, said heating assembly including a third heating device for the feed unit for heating the solid material.

27. A method of molding a metallic material, comprising the steps of:
   - continuously preparing metallic material in free-flowing form;
   - feeding the metallic material to a storage container with constant volume and variable fill level;
   - periodically transferring the metallic material into an injection unit with a piston and cylinder arrangement; and
   - injecting the metallic material by the injecting unit into a molding tool, wherein the piston and cylinder arrangement of the injection unit and the storage container are heated separately and independently from one another.

28. The method of claim 27, wherein the preparing step includes the step of heating a starting material to a temperature above a solidus temperature but not exceeding a liquidius temperature so that the thus-prepared metallic material has liquid and solid phases.

29. The method of claim 28, wherein the preparing step includes the step of heating a starting material to a temperature above a liquidius temperature so that the thus-prepared metallic material has a completely liquid phase.

30. The method of claim 27, wherein the prepared metallic material in the storage container is subject to a shearing action to reduce forming dendritic structures.

31. The method of claim 27, wherein the prepared metallic material in the storage container is maintained under an inert gas volume.

32. The method of claim 27, wherein the piston and cylinder arrangement has a piston which is actively moved independently on the introduction of metallic material into the injection unit.

33. The method of claim 28, wherein the starting material is a solid material.

34. The method of claim 28, wherein the starting material is pre-heated.

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