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(54) **Die casting system and method**

(57) A die casting system (50) includes a die (52) having a plurality of die elements (52, 54) that define a die cavity (60). A charge of material (M) is received in

the die cavity (60). The charge of material (M) comprises a refractory metal intermetallic composite based material system.

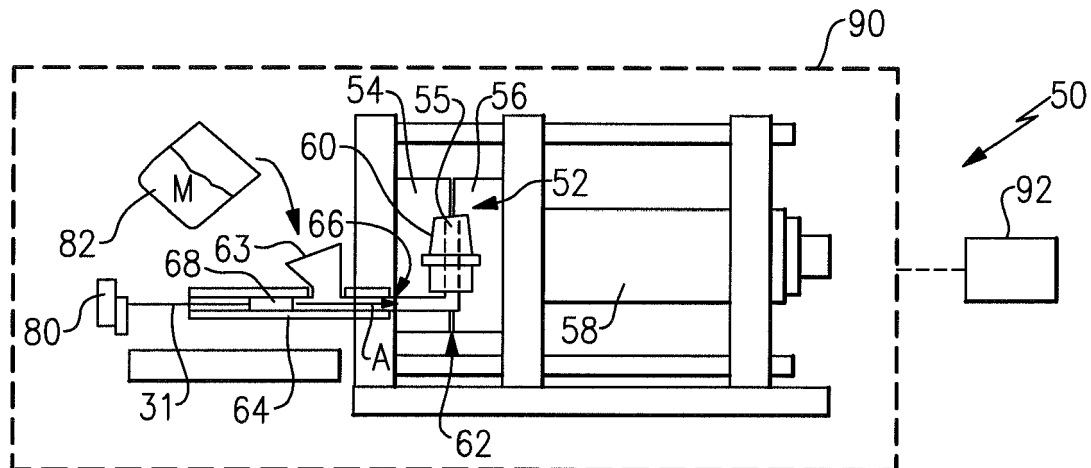


FIG.1

Description

BACKGROUND

[0001] This disclosure relates generally to casting, and more particularly to a die casting system and method.

[0002] Casting is a known technique used to yield near net-shaped components. For example, investment casting is often used in the gas turbine engine industry to manufacture blades, vanes and other components having relatively complex geometries. A component is investment cast by pouring molten metal into a ceramic shell having a cavity in the shape of the component to be cast. Generally, the shape of the component is derived from a wax or SLA pattern that defines the shape of the component. The investment casting process is capital intensive, requires a significant amount of manual labor, and can be time intensive.

[0003] Die casting offers another casting technique. Die casting involves injecting molten metal directly into a reusable die to yield a near net-shaped component. The tooling of the die casting system, including the die, the shot tube and the shot tube plunger, are subjected to relatively high thermal loads and stresses during the die casting process.

SUMMARY

[0004] A die casting system disclosed herein includes a die having a plurality of die elements that define a die cavity. A charge of material is received in the die cavity. The charge of material comprises a refractory metal intermetallic composite based material system.

[0005] In another exemplary embodiment, a die casting system includes a die having a plurality of die elements that define a die cavity. A charge of material is received in the die cavity. The charge of material can include a composite material such as niobium silicide, molybdenum di-silicide, $\text{Nb}_5\text{Si}_3+\text{NbO}+\text{SiO}_2$, $\text{NbSi}_2+\text{Nb}_5\text{Si}_3+\text{SiO}_2$, $\text{TaSi}_2+\text{Ta}_5\text{Si}_3+\text{SiO}_2$, $\text{W}_5\text{Si}_3+\text{W}+\text{SiO}_2$, and $\text{WSi}_2+\text{W}_5\text{Si}_3+\text{SiO}_2$.

[0006] An exemplary method of die casting a component includes injecting a charge of material into a die having a plurality of die elements that define a die cavity configured to receive the charge of material. The charge of material comprises a refractory metal intermetallic composite based material system.

[0007] The various features and advantages of this disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Figure 1 illustrates a die casting system.

Figure 2A illustrates the die casting system of Figure 1 during casting of the component.

Figure 2B illustrates the die casting system of Figure 1 upon separation from the casting component.

Figure 3 illustrates additional features that can be incorporated into a die casting system.

Figure 4 illustrates a component cast in a die casting process.

DETAILED DESCRIPTION

[0009] Figure 1 illustrates an example die casting system 50 including a reusable die 52 having a plurality of die elements 54, 56 that function to cast a component 55 (See Figure 4). Although two die elements 54, 56 are depicted in Figure 1, it should be understood that the die 52 could include a greater or fewer number of die elements, as well as other parts and configurations.

[0010] The die 52 is assembled by positioning the die elements 54, 56 together and holding the die elements 54, 56 at a desired positioning via a mechanism 58. The mechanism 58 could include a clamping mechanism of appropriate hydraulic, pneumatic, electromechanical and/or other configurations. The mechanism 58 also separates the die elements 54, 56 subsequent to casting.

[0011] The die elements 54, 56 define internal surfaces 62 that cooperate to define a die cavity 60. A shot tube 64 is in fluid communication with the die cavity 60 via one or more ports 66 located in the die element 54, the die element 56 or both. A shot tube plunger 68 is received within the shot tube 64 and is moveable between a retracted and injected position (in the direction of arrow A) within the shot tube 64 by a mechanism 80. A shot rod 31 extends between the mechanism 80 and the shot tube plunger 68. The mechanism 80 could include a hydraulic assembly or other suitable system including, but not limited to, pneumatic, electromechanical, hydraulic or any combination of the systems.

[0012] The shot tube 64 is positioned to receive a charge of material M from a melting unit 82, such as a crucible, for example. The melting unit 82 can utilize any known technique for melting an ingot of metallic material to prepare the charge of material M for delivery to the shot tube 64, including but not limited to, vacuum induction melting, electron beam melting, induction skull melting and resistance melting. The charge of material M is melted into molten metal in the melting unit 82 at a location that is separate from the shot tube 64 and the die cavity 60. In this example, the melting unit 82 is positioned in close proximity to the shot tube 64 to reduce the required transfer distance between the charge of material M and the shot tube 64.

[0013] The charge of material M is transferred from the melting unit 82 to the shot tube 64 in a known manner, such as pouring the charge of material M into a pour hole 63 in the shot tube 64, for example. A sufficient amount of molten metal is poured into shot tube 64 to fill the die cavity 60. The shot tube plunger 68 is actuated to inject

the charge of material M under pressure from the shot tube 64 into the die cavity 60 to cast a component 55. Although a single component 55 is depicted, the die casting system 50 could be configured to cast multiple components in a single shot.

[0014] Although not necessary, at least a portion of the die casting system 50 can be positioned within a vacuum chamber 90 that includes a vacuum source 92. A vacuum is applied in the vacuum chamber 90 via the vacuum source 92 to render a vacuum die casting process. The vacuum chamber 90 provides a non-reactive environment for the die casting system 50 and reduces reaction, contamination or other conditions that could detrimentally affect the quality of the die cast component, such as excess porosity in the cast component resulting from exposure to air.

[0015] In one example, the vacuum chamber 90 is maintained at a pressure 5×10^{-3} Torr (0.66 Pascal) and 1×10^{-6} Torr (0.000133 Pascal), although other pressures are contemplated. The actual pressure of the vacuum chamber 90 will vary based on the type of component 55 cast, among other conditions and factors. In the illustrated example, each of the melting unit 82, the shot tube 64 and the die 52 are positioned within the vacuum chamber 90 during the die casting process such that the melting, injecting and solidifying of the charge of material M are each performed under vacuum. In another example, the vacuum chamber 90 is vacuum filled with an inert gas, such as argon, for example.

[0016] The example die casting system 50 depicted by Figure 1 is illustrative only and could include a greater or fewer number of sections, parts and/or components. This disclosure extends to all forms of die casting, including but not limited to, horizontal, vertical, inclined or other die casting configurations.

[0017] Figures 2A and 2B illustrate portions of the die casting system 50 during casting (Figure 3A) and after the die elements 54, 56 separate (Figure 3B). After the charge of material M solidifies within the die cavity 60, the die elements 54, 56 are disassembled relative to the component 55 by opening the die 52 via the mechanism 58. In one example, ejector pins 84 are used to remove the components 55 from the die cavity 60.

[0018] A die release agent may be applied to the die elements 54, 56 of the die 52 prior to injection to achieve a simpler release of the component 55 from the die 52 post-solidification. The cast component 55 may include an equiaxed structure upon solidification, or could include other structures. An equiaxed structure includes a randomly oriented grain structure having multiple grains.

[0019] In one example, a composite material is used to die cast the component 55. In this disclosure, "composite" is defined as a refractory metal intermetallic composite (or, RMIC). RMIC's contain a member or members of the family of refractory elements. These elements include tungsten, rhenium, tantalum, molybdenum, and niobium. These elements are combined with an intermetallic element such as silicon. Example composites in-

clude, but are not limited to, niobium silicide (NbSi) and molybdenum di-silicide (MoSi₂). Further included are the following example composites: Nb₅Si₃+NbO+SiO₂; NbSi₂+Nb₅Si₃+SiO₂; TaSi₂+Ta₅Si₃+SiO₂; W₅Si₃+W+SiO₂; and WSi₂+W₅Si₃+SiO₂.

[0020] Additional intermetallic compounds include, but are not limited to, Nickel Aluminides of general composition NiAl and Ni₃Al (but can contain alloying elements such as: Co, Cr, Pt, Si, Re, Rh, Ta, Y, Er, Gd, Zr and/or Hf); Titanium Aluminide of the general compositions TiAl, TiAl₂, TiAl₃ (but can contain alloying elements such as Mn, V, Nb, Ta, Fe, Co, Cr, Ni, B, W, Mo, Cu, Zr, and/or Si); and Platinum Aluminide of general composition PtAl (but can contain alloying elements such as, but not limited to, Ni, Co, Cr, Pt, Si, Rh, Ta, Y, Er, Gd, and/or Hf).

[0021] Die casting components using a charge of material such as the RMIC's noted above provides an improved casting process without the need to develop or reengineer the ceramic systems that are used in a traditional investment casting process.

[0022] Figure 3 illustrates additional features that can be incorporated into the die casting system 50. The die elements 54, 56 can be selectively heated with a heating system 100, such as a die heater, if necessary. In addition, die inserts of the die elements 54, 56 can include layers of a highly conductive material to aid in the temperature control of the die inserts. Example highly conductive materials could include a thermal conductivity of at least 310 W/m²K and a melting temperature of at least 960°C (1760°F). Materials such as copper, gold and silver are examples of such highly conductive materials that can be used in the construct of portions of the die elements 54, 56. The highly conductive material rapidly conducts heat away from the die elements 54, 56 during the casting process to extend tooling life.

[0023] The die elements 54, 56 can also be selectively cooled with a cooling system 104 as necessary due to the extreme heat experienced during the casting process. For example, a die casting hot oil technology can be used, or other radiative or conductive cooling techniques such as liquid metal cooling, in order to cool the die elements 54, 56 and a die base 102 during the casting process.

[0024] Figure 4 illustrates an example component 55 that can be cast in a die casting process. In this example, the component 55 is an airfoil for a gas turbine engine. However, this disclosure is not limited to the casting of airfoils. For example, the example die casting system 50 of this disclosure may be utilized to cast aeronautical components including blades, vanes, combustor panels, blade outer air seals (boas), or any other components that could be subjected to extreme environment, including non-aeronautical components.

[0025] The die cast component 55 can include an internal geometry 38 defined within the component 55 (i.e., the component 55 is at least partially hollow). In this example, the internal geometry 38 defines a microcircuit

cooling scheme for a turbine vane. However, the internal geometry 38 could also define other advanced cooling schemes to facilitate additional heat transfer. Additionally, weight reduction tongues (i.e., voids) can be included to reduce the rotational inertia and/or weight of the final component.

[0026] The component 55, including its internal geometry 38, can be cast using the example die casting system 50 described above. Die casting of the component 55 with the materials noted above allows for the production of a fine, uniform grain size that will improve the properties and materials. Furthermore, solidification rates will be increased significantly by transitioning refractory metal alloys and/or composite to die casting. Additionally, the rapid melting of the charge of material from ingot stock reduces the potential for reactivity with the die casting system 50 tooling due to the ability of the die casting tooling to disperse heat away from the final casting geometry. In other words, the bulk of the die tooling is able to absorb the heat and effectively move it to other areas of the die.

[0027] The foregoing description shall be interpreted as illustrative and not in any limiting sense. A worker of ordinary skill in the art would understand that certain modifications could come within the scope of this disclosure. For these reasons, the following claims should be studied to determine the true scope and content of this disclosure.

Claims

1. A method of die casting a component (55), comprising the step of:

injecting a charge of material (M) into a die (52) having one or a plurality of die elements (54, 56) that define a die cavity (60) configured to receive the charge of material (M), wherein the charge of material (M) includes a refractory metal intermetallic composite based material system.

2. A die casting system (50), comprising:

a die (52) having one or a plurality of die elements (54, 56) that define a die cavity (58) configured to receive a charge of material (M), wherein said charge of material (M) comprises a refractory metal intermetallic composite based material system.

3. The method or die casting system as recited in claim 1 or 2, wherein said refractory metal intermetallic composite based material system includes niobium silicide (NbSi).

4. The method or die casting system as recited in claim 1, 2 or 3, wherein said refractory metal intermetallic composite based material system includes molyb-

denum di-silicide (MoSi₂).

5. The method or die casting system as recited in any preceding claim, wherein said refractory metal intermetallic composite based material system includes a composite material selected from the group consisting of Nb₅Si₃+NbO+SiO₂; NbSi₂+Nb₅Si₃+SiO₂; TaSi₂+Ta₅Si₃+SiO₂; W₅Si₃+W+SiO₂; and WSi₂+W₅Si₃+SiO₂.
6. The method or die casting system as recited in any preceding claim, wherein said refractory metal intermetallic composite based material system includes a nickel aluminide based composite material.
7. The method or die casting system as recited in any preceding claim, wherein said refractory metal intermetallic composite based material system includes a titanium aluminide based composite material.
8. The method or die casting system as recited in any preceding claim, wherein said refractory metal intermetallic composite based material system includes a platinum aluminide based composite material.
9. The die casting system as recited in any of claims 2 to 8, comprising a shot tube (64) in fluid communication with said die cavity (60), and a shot tube plunger (68) moveable within said shot tube (64) to communicate said charge of material (M) into said die cavity (60).
10. The die casting system as recited in any of claims 2 to 9, wherein a portion of said die casting system (50) includes a highly conductive material.
11. The die casting system as recited in claim 10, wherein said die elements (54, 56) include said highly conductive material.
12. The die casting system as recited in claim 10 or 11, wherein said highly conductive material includes a thermal conductivity of at least of at least 310 W/m*K and a melting temperature of at least 960°C (1760°F).
13. The die casting system as recited in any of claims 2 to 12, comprising a heating system (100) that selectively heats said die elements (54, 56).
14. The die casting system as recited in any of claims 2 to 13, comprising a cooling system (104) that selectively cools said die elements (54, 56).
15. The die casting system as recited in claim 14, wherein said cooling system (104) includes liquid metal cooling or hot oil technology.

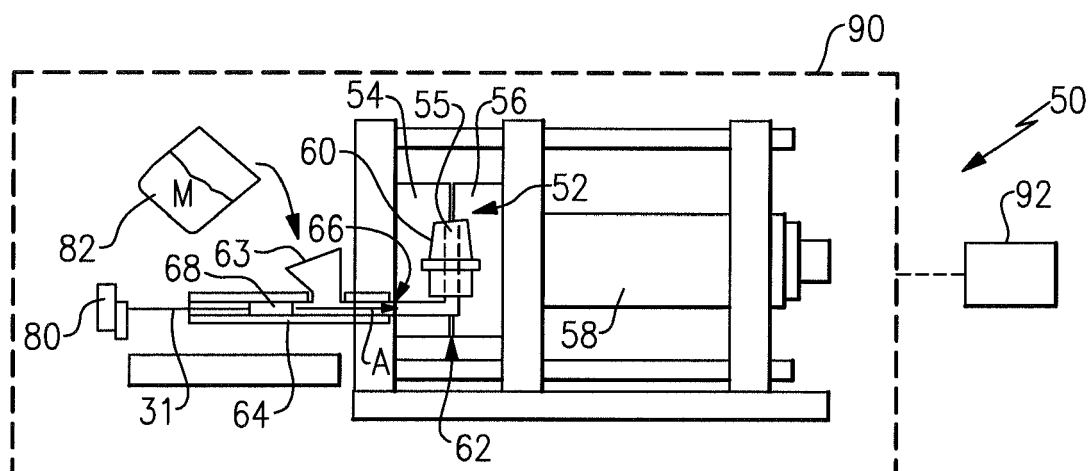


FIG. 1

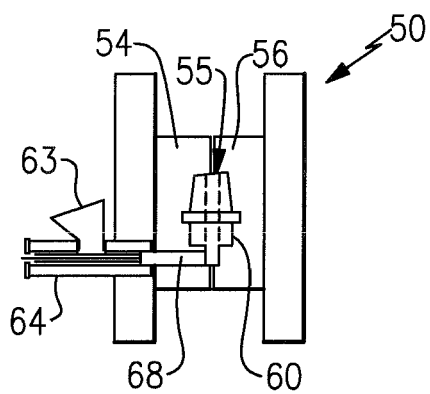


FIG. 2A

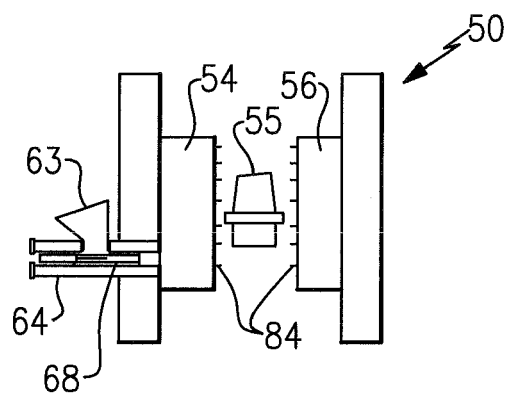


FIG. 2B

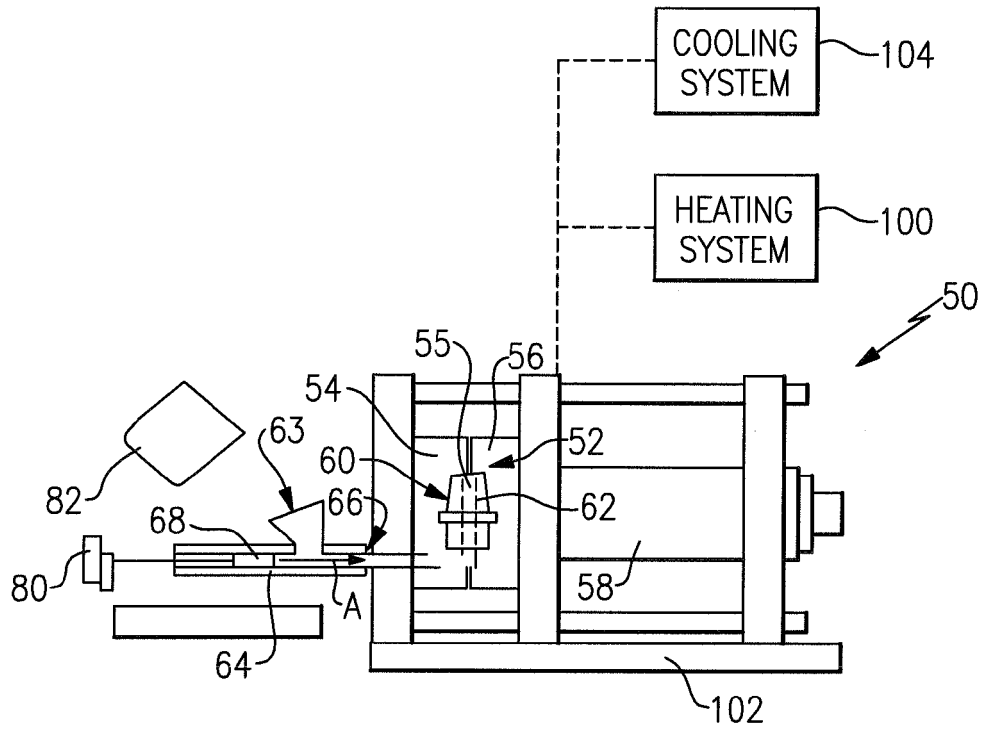


FIG. 3

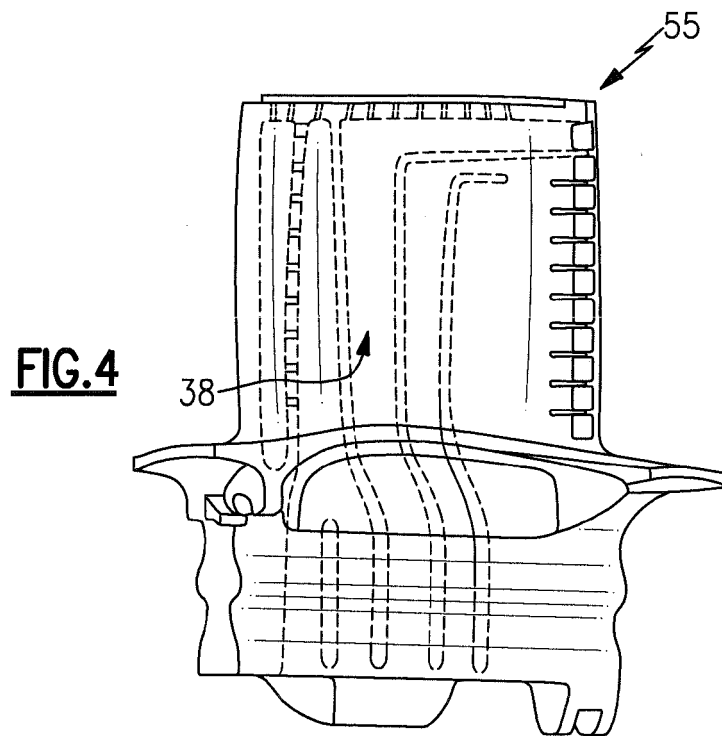


FIG. 4