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(54) DIE CASTING SYSTEM AND METHOD

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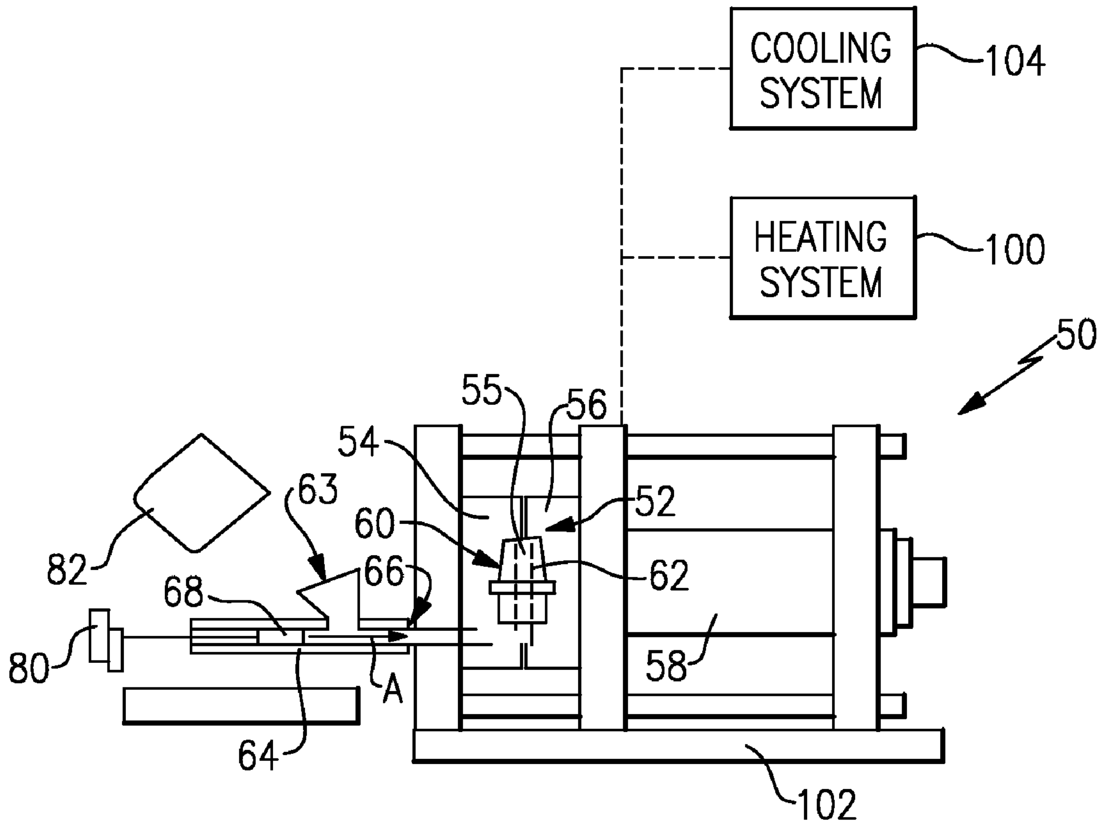
(57) ABSTRACT

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 may comprises a refractory metal intermetallic composite based material system. The charge of material may also comprise a composite material.



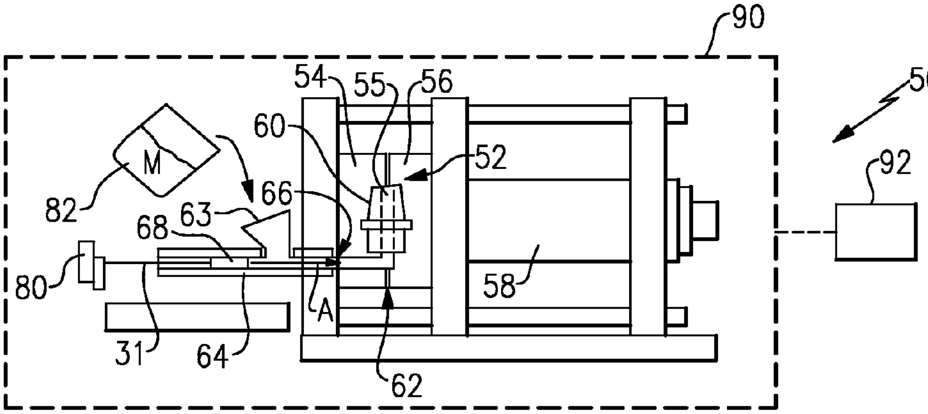


FIG.1

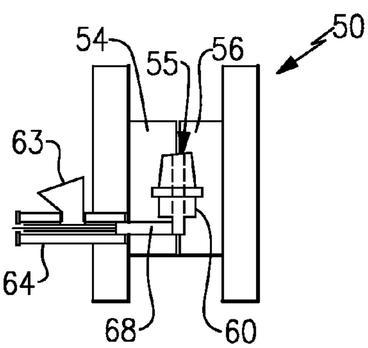


FIG.2A

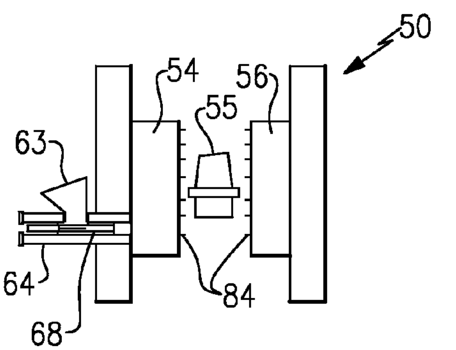


FIG.2B

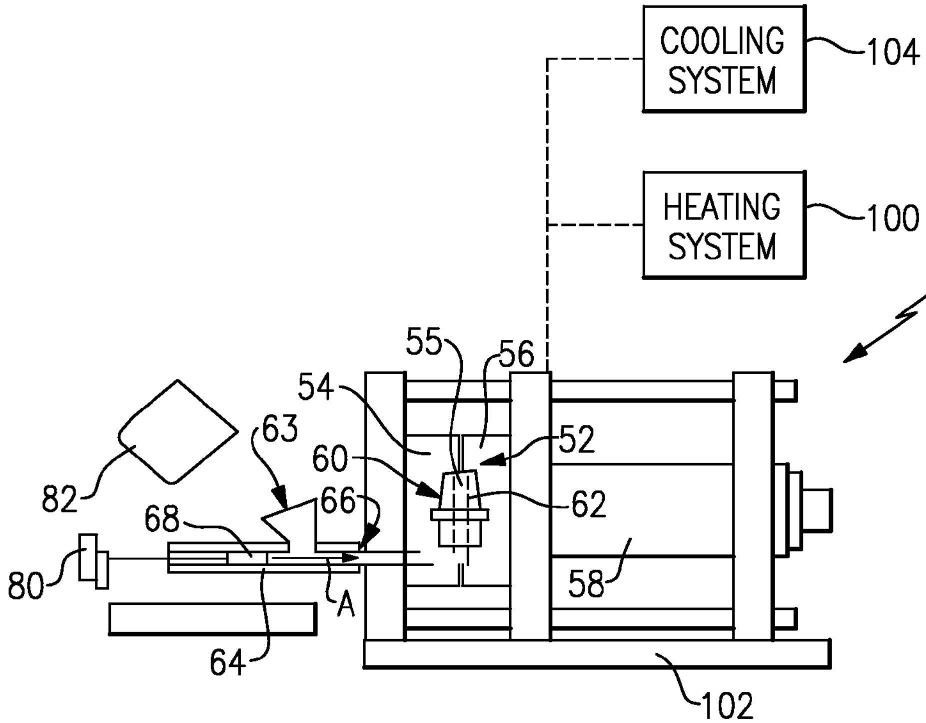

COOLING SYSTEM
104
HEATING SYSTEM
100
50
55
56
54
52
63
60
82
62
66
68
80
58
A
64
102

FIG.3

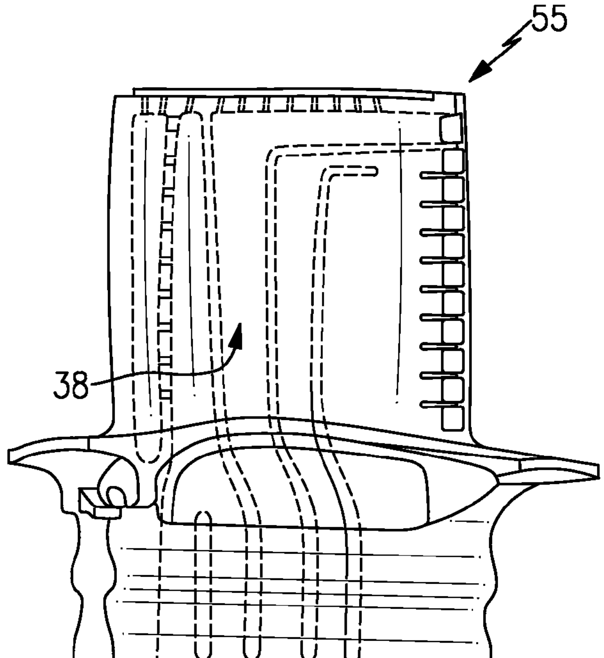

55
38

FIG.4

DIE CASTING SYSTEM AND METHOD

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 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, Nb_5Si_3+NbO+SiO_2, $NbSi_2$+Nb_5Si_3+SiO_2, $TaSi_2$+Ta_5Si_3+SiO_2, W_5Si_3+W+SiO_2, and WSi_2+W_5Si_3+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] FIG. **1** illustrates a die casting system.

[0009] FIG. **2**A illustrates the die casting system of FIG. **1** during casting of the component.

[0010] FIG. **2**B illustrates the die casting system of FIG. **1** upon separation from the casting component.

[0011] FIG. **3** illustrates additional features that can be incorporated into a die casting system.

[0012] FIG. **4** illustrates a component cast in a die casting process.

DETAILED DESCRIPTION

[0013] FIG. **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 FIG. **4**). Although two die elements **54**, **56** are depicted in FIG. **1**, it should be understand that the die **52** could include a greater or fewer number of die elements, as well as other parts and configurations.

[0014] 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.

[0015] 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.

[0016] 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**.

[0017] 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.

[0018] 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.

[0019] In one example, the vacuum chamber **90** is maintained at a pressure 5×10^{-3} Ton (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.

[0020] The example die casting system **50** depicted by FIG. **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.

[0021] FIGS. **2**A and **2**B illustrate portions of the die casting system **50** during casting (FIG. **3**A) and after the die elements **54**, **56** separate (FIG. **3**B). After the charge of material M solidifies within the die cavity **70**, 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**.

[0022] 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.

[0023] 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 include, but are not limited to, niobium silicide (NbSi) and molybdenum di-silicide (MoSi2). Further included are the following example composites: Nb_5Si_3+NbO+SiO_2; $NbSi_2$+Nb_5Si_3+SiO_2; $TaSi_2$+Ta_5Si_3+SiO_2; W_5Si_3+W+SiO_2; and WSi_2+W_5Si_3+SiO_2.

[0024] 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).

[0025] 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.

[0026] FIG. **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/m*K 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.

[0027] 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.

[0028] FIG. **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 environments, including non-aeronautical components.

[0029] 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.

[0030] 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.

[0031] 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.

1. A die casting system, comprising:

a die having a plurality of die elements that define a die cavity;

a charge of material communicated into said die cavity, wherein said charge of material comprises a refractory metal intermetallic composite based material system.

2. The die casting system as recited in claim **1**, comprising a shot tube in fluid communication with said die cavity, and a shot tube plunger moveable within said shot tube to communicate said charge of material into said die cavity.

3. The die casting system as recited in claim **1**, wherein a portion of said die casting system includes a highly conductive material.

4. The die casting system as recited in claim **3**, wherein said die elements include said highly conductive material.

5. The die casting system as recited in claim **3**, 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.).

6. The die casting system as recited in claim **1**, comprising a heating system that selectively heats said die elements.

7. The die casting system as recited in claim **1**, comprising a cooling system that selectively cools said die elements.

8. The die casting system as recited in claim **7**, wherein said cooling system includes liquid metal cooling.

9. (canceled)

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

11. The die casting system as recited in claim **1**, wherein said refractory metal intermetallic composite based material system includes molybdenum di-silicide (NbSi2).

12. The die casting system as recited in claim **1**, wherein said refractory metal intermetallic composite based material system includes a composite material selected from the group consisting of Nb_5Si_3+NbO+SiO_2; $NbSi_2$+Nb_5Si_3+SiO_2; $TaSi_2$+Ta_5Si_3+SiO_2; W_5Si_3+W+SiO_2; and WSi_2+W_5Si_3+SiO_2.

13-15. (canceled)

16. A die casting system, comprising:

a die having at least one die elements that defines a die cavity;

a charge of material communicated into said die cavity, wherein said charge of material comprises a composite material selected from the group consisting of niobium silicide, molybdenum di-silicide, Nb_5Si_3+NbO+SiO_2, $NbSi_2$+Nb_5Si_3+SiO_2, $TaSi_2$+Ta_5Si_3+SiO_2, W_5Si_3+W+SiO_2, and WSi_2+W_5Si_3+SiO_2.

17. The die casting system as recited in claim **16**, wherein said die elements includes a highly conductive material.

18-20. (canceled)

21. The die casting system as recited in claim **1**, comprising a vacuum chamber and a vacuum source that applies a vacuum to said vacuum chamber.

22. The die casting system as recited in claim **1**, comprising a heating system that selectively heats said plurality of die elements and a cooling system that selectively cools said plurality of die elements.

23. The die casting system as recited in claim **22**, wherein said heating system includes a die heater and said cooling system includes liquid metal cooling.

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