

DIE CASTING SYSTEM AND METHOD UTILIZING HIGH MELTING TEMPERATURE MATERIALS

BACKGROUND

5 This disclosure relates generally to casting and, more particularly, to a die casting system for casting high temperature materials.

 Die casting involves injecting molten metal directly into a reusable die to yield a net-shaped component. Die casting has typically been used to produce components that do not require high thermal mechanical performance. For example, die casting is
10 commonly used to produce components made from relatively low melting temperature metals, such as, but not limited to: aluminum, zinc, magnesium, and copper. The products produced from these alloy systems are not generally subjected to extreme operating conditions.

 Gas turbine engines include multiple components that are subjected to extreme
15 temperatures during operation. For example, the compressor section and turbine section of the gas turbine engine each include blades and vanes that are subjected to relatively extreme temperatures, such as temperatures exceeding approximately 1500°F/815°C.

 Gas turbine engine components for use in these applications are produced
20 through several processes, such as, but not limited to, investment casting and forging. Investment casting involves 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 to be produced is derived from a wax pattern or SLA pattern to form the exterior shape of the component. The investment casting process is capital intensive, requires
25 significant manual labor, and can be time intensive to produce the final component. Forging of a component is accomplished through the application of localized forces to the desired metal using shaped tooling to plastically deform the metal into the final shape. While forging is generally less expensive than investment casting there is still a significant amount of lead time and capital investment required to produce
30 components by this methodology. Wrought product can be subsequently machined into the desired shape, but is less cost effective for large volumes of components due to excessive material losses due to machining.

SUMMARY

An example die casting system includes a die comprised of a plurality of die components that define a die cavity, metal delivery system, and part removal system configured to receive a molten metal. One or more of the die components comprises a material or materials that are suitable for use with the molten metal and has a melting temperature above 815 degrees Celsius.

An example die casting system includes a die comprised of a plurality of die components that define a die cavity configured to receive a molten metal, wherein at least one of the plurality of die components comprises a material selected from a group consisting of a nickel based super alloy, a cobalt based super alloy, an iron-nickel based super alloy, a suitably alloyed iron based alloy, a suitably alloyed copper alloy, and a refractory metal alloy where the refractory metal is either: tungsten, molybdenum, rhenium, niobium, or tantalum.

An example die casting system includes a die comprised of a plurality of die components that define a die cavity configured to receive a molten metal that has a melting temperature above 815 degrees Celsius. One of the die components comprises a ceramic material, or a composite material such as: a metal matrix composite, a ceramic matrix composite, or a combination of independent ceramic and metallic components that comprise the die components.

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

Figure 1 illustrates an example die casting system used to cast components.

Figure 2 illustrates an example component cast with the die casting system of Figure 1.

Figure 3A illustrates the die casting system of Figure 1 during casting of a component.

Figure 3B illustrates the die casting system of Figure 1 upon separation from a casted component.

DETAILED DESCRIPTION

Referring to Figures 1 and 2, 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. Although two die elements 54, 56 are depicted in Figure 1, it should
5 be understood that the die 52 could include more or fewer die elements, as well as other parts and configurations.

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,
10 pneumatic, electromechanical and/or other configurations. The mechanism 58 also separates the die elements 54, 56 subsequent to casting.

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.

15 A plunger tip and rod 68 are received within the shot tube 64 and is moveable between a retracted and injection position (in the direction of arrow A) within the shot tube 64 by a mechanism 80. The mechanism 80 could include a hydraulic assembly or other suitable mechanism, including, but not limited to, hydraulic, pneumatic, electromechanical, or any combination thereof.

20 The shot tube 64 is positioned to receive a molten metal from a melting unit 82, such as a crucible, for example. The melting unit 82 may utilize any known technique for melting an ingot of metallic material to prepare a molten metal 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 molten
25 metal to be used to manufacture the part is melted 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 molten metal and the shot tube 64.

Example molten metals capable of being used to die cast a component 55
30 include, but are not limited to, nickel based super alloys, titanium alloys, high temperature aluminum alloys, copper based alloys, iron alloys, molybdenum, tungsten, niobium, or other refractory metals. This disclosure is not limited to the disclosed alloys, and it should be understood that any material having a high melting

temperature may be utilized to die cast the component 55. As used herein, the term “high melting temperature” is intended to describe component materials having a melting temperature of approximately 1500°F/815°C or higher.

5 The molten metal is transferred from the melting unit 82 to the shot tube 64 in a known manner, such as pouring the molten metal into a pour hole 63 in the shot tube 64, for example. A sufficient amount of molten metal is poured into the shot tube 64 to fill the die cavity 60. The shot tube plunger 68 is actuated to inject the molten metal under pressure from the shot tube 64 into the die cavity 60 to cast the component 55. Although the casting of a single component is depicted, the die
10 casting system 50 could be configured to cast multiple components in a single shot.

The example die casting system 50 depicted in Figure 1 is illustrative only and could include more or less sections, parts and/or components. This disclosure extends to all forms of die casting, including but not limited to, horizontal or vertical, or inclined die casting systems.

15 Figures 3A and 3B illustrate portions of the die casting system 50 during casting (Figure 3A) and after the die elements 54, 56 separate (Figure 3B). After the molten metal 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 move the component 55 from the die
20 cavity 60.

The example die casting system 50 includes portions that are made from high temperature system materials that are able to withstand high temperatures associated with casting the molten metal into the component 55.

25 In one example, the die elements 54, 56 are made entirely of the high temperature system material.

In another example, a portion of the die elements 54, 56 are made of the high temperature system material. The areas of the cavity 70 establishing areas of the component 55 prone to microfractures or thermo-mechanical induced fatigue, such as tight radii areas of the cast component, could be made of the high temperature system
30 material. Also, the areas of the die elements 54, 56 establishing the cavity could be coated with the high temperature system material.

In addition to the die elements 54, 56, portions of the shot tube 64, the shot tube plunger 68, or the ejector pins 84 include the high temperature system material in some examples.

Notably, the example high temperature system material does not reactively
5 interact with the molten material. That is, there is no substantial chemical reaction, melting, welding, soldering, or alloying between the high temperature system material and the molten material.

Many techniques could be used to incorporate the high temperature system material into the die casting system 50. For example, the die elements 54, 56 could
10 incorporate the high temperature system material by casting, machining, slip casting, injection molding, isostatic pressing (hot or cold), sintering, stamping, forging, direct metal laser sintering etc.

Example materials that could be used as the high temperature system material include metallic materials, such as a nickel based super alloy, a cobalt based super
15 alloy, a iron-nickel based super alloy, a suitably alloyed iron based alloy, a suitably alloyed copper alloy, or a refractory metal (tungsten, molybdenum, rhenium, niobium, or tantalum) based alloy. These materials can be manufactured into suitable die blocks using a variety of processing techniques including, but not limited to: cold forging, hot forging, conventional casting, directional solidified casings with or
20 without orientation control, extrusions, or hot isostatic compaction of powder metallurgy products. Example nickel based super alloys include: IN100, IN713C, IN792 forged; First generation nickel base single crystal alloys (0% Rhenium) such as US 4209348, US4597809; Second generation nickel base single crystal alloys (3% Rhenium) such as US4719080; Third generation nickel base single crystal alloys (6%
25 Rhenium) such as US5366695; Fourth generation nickel base single crystal alloys (6% Rhenium, 3% Ruthenium) such as US6007645; Fifth generation nickel base nickel base single crystal alloys (6+% Rhenium, 6+% Ruthenium) such as TMS-173; Directionally solidified first generation (0% Rhenium) columnar structure alloys such as US3785809; and second generation (3% Rhenium) columnar structure alloys such
30 as US5068084. Example nickel-iron super alloys include Invar 909, IN718. Example alloyed based iron alloys include: H23, H42, M35, M36, M42, M46, M62 and Greek Ascoloy. Example cobalt cast alloys include Mar-M-509, and Stellite 31. Example refractory metal alloys include: Anvilloy 1150, TZM (tungsten-molybdenum-

zirconium), molybdenum-rhenium systems, tantalum -10% tungsten, and tungsten-rhenium systems.

Example materials that can be used as the high temperature system material include ceramic materials, such as boron nitride, silicon nitride, silicon aluminum oxy
5 nitride (SiAlON), aluminum nitride, aluminum oxide, silicon carbide, titanium carbide, tungsten carbide, zirconium oxide, boron carbide, titanium diboride, niobium boride, zirconium boride, hafnium diboride, niobium carbide, zirconium carbide, hafnium carbide, graphite etc.

Example materials that can be used as the high temperature system material
10 include metal matrix composite materials, such as copper-tungsten, copper-molybdenum, copper-molybdenumcopper-copper, copper-niobium, Silvar, aluminium silicon carbide.

Example materials that can be used as the high temperature system material include ceramic matrix composite materials, such as C-SiC, SiC-SiC, SiC-Si₃N₄, C-
15 ZrC, C-HfC, C-SiC-ZrC, C-SiC-HfC, C-TaC and C-TaC-HfC.

The example component 55 is casted using the example die casting system 50 described above. In this example, the die casted component 55 is a blade for the gas turbine engine (not shown), such as a turbine blade for a turbine section of the gas turbine engine. However, this disclosure is not limited to the casting of blades. For
20 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, or any other component subjected to extreme environments, including non-aeronautical components.

The example component 55 includes tightly radiused areas 86 that are more
25 susceptible to thermo mechanical fatigue than other areas of the component 55. The areas of the die elements 54, 56 that interface with the areas 86 include a layer of high temperature system material, for example.

Features of the disclosed examples include a die casting system that includes system materials that have a relatively high melt point and that are non-reactive
30 with a component material. The system materials facilitate die casting of components that are made from component materials having a high melt point. The system materials reduce thermo-mechanical fatigue in the cast component. The system

materials are effective for moving thermal energy away from the cast component. The system materials absorb the heat input from molten metals.

The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. Thus, the scope of legal protection given to this disclosure can only be determined by studying the following claims.

CLAIMS

1. A die casting system, comprising:
a die comprised of a plurality of die components that define a die cavity
5 configured to receive a molten metal, wherein at least one of the plurality of die
components comprises a material that is not reactive with the molten metal and has a
melting temperature above 815 degrees Celsius.
2. The die casting system of claim 1, comprising a shot tube in fluid
10 communication with said die cavity, a shot tube plunger moveable within said shot
tube to communicate the molten metal into said die cavity, wherein at least one of the
shot tube and the shot tube plunger comprises the material.
3. The die casting system of claim 2, wherein a tip of the shot tube plunger
15 comprises the material.
4. The die casting system of claim 1, comprising at least one ejector pin
configured to be moved relative to the die cavity, wherein the at least one ejector pin
comprises the material.
20
5. A die casting system, comprising:
a die comprised of a plurality of die components that define a die cavity
configured to receive a molten metal, wherein at least one of the plurality of die
components comprises a material selected from a group consisting of a nickel based
25 super alloy, a cobalt based super alloy, an iron-nickel based super alloy, a suitably
alloyed iron based alloy, a suitably alloyed copper alloy, and a refractory metal based
alloy.
6. The die casting system of claim 5, comprising a shot tube in fluid
30 communication with said die cavity and a shot tube plunger moveable within said shot
tube to communicate the molten metal into said die cavity, wherein at least one of the
shot tube and the shot tube plunger comprises the material.

7. The die casting system of claim 6, wherein a tip of the shot tube plunger comprises the material.
8. The die casting system of claim 5, comprising at least one ejector pin
5 configured to be moved relative to the die cavity, wherein the ejector pin comprises the material.
9. The die casting system of claim 5, wherein the at least one of the plurality of die components comprises a die.
- 10
10. The die casting system of claim 5, wherein another of the plurality of die components comprises a material that is not in the group.
11. The die casting system of claim 5, wherein the refractory metal comprises a
15 material selected from a group consisting of tungsten, molybdenum, rhenium, niobium, and tantalum.
12. A die casting system, comprising:
a die comprised of a plurality of die components that define a die cavity
20 configured to receive a molten metal that has a melting temperature above 815 degrees Celsius, wherein at least one of the plurality of die components comprises a material that is a ceramic material, a metal matrix composite material, a ceramic matrix composite material, or some combination of these.
- 25 13. The die casting system of claim 12, comprising a shot tube in fluid communication with said die cavity and a shot tube plunger moveable within said shot tube to communicate the molten metal into said die cavity, wherein at least one of the shot tube and the shot tube plunger comprises the material.
- 30 14. The die casting system of claim 13, wherein the leading contact surface of the plunger tip or the entire plunger comprises the material.

15. The die casting system of claim 12, wherein the material comprises a material selected from a group consisting of boron nitride, silicon nitride, silicon aluminum oxy nitride (SiAlON), aluminum nitride, aluminum oxide, silicon carbide, titanium carbide, tungsten carbide, zirconium oxide, boron carbide, titanium diboride, niobium boride, zirconium boride, hafnium diboride, niobium carbide, zirconium carbide, hafnium carbide, and graphite.

16. The die casting system of claim 15, comprising a shot tube in fluid communication with said die cavity and a shot tube plunger moveable within said shot tube to communicate the molten metal into said die cavity, wherein at least one of the die components and the shot tube plunger comprises the material.

17. The die casting system of claim 15, comprising at least one ejector pin configured to be moved relative to the die cavity, wherein the ejector pin comprises the material.

18. The die casting system of claim 12, wherein the metal matrix composite material comprises a material selected from a group consisting of copper-tungsten, copper-molybdenum, copper-molybdenumcopper-copper, copper-niobium, Silvar, aluminium silicon carbide.

19. The die casting system of claim 12, wherein the ceramic material comprises a material selected from a group consisting of C-SiC, SiC-SiC, SiC-Si₃N₄, C-ZrC, C-HfC, C-SiC-ZrC, C-SiC-HfC, C-TaC and C-TaC-HfC.