(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 153 151 B1**

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
21.02.2007 Bulletin 2007/08

(21) Application number: **99968962.3**

(22) Date of filing: **22.12.1999**

(51) Int Cl.:
C22C 19/07 $^{(2006.01)}$ *C22C 19/05* $^{(2006.01)}$
C22C 1/02 $^{(2006.01)}$

(86) International application number:
PCT/US1999/031000

(87) International publication number:
WO 2000/037695 (29.06.2000 Gazette 2000/26)

(54) DIE CAST SUPERALLOY ARTICLES

SUPERLEGIERUNGSDRUCKGUSSTEILE

PIECES MOULEES SOUS PRESSION EN SUPERALLIAGE

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **23.12.1998 US 113567 P**

(43) Date of publication of application:
14.11.2001 Bulletin 2001/46

(73) Proprietor: **UNITED TECHNOLOGIES CORPORATION**
Hartford,
Connecticut 06101 (US)

(72) Inventors:
- **SCHIRRA, John, Joseph**
  Ellington, CT 06029 (US)
- **BORG, Christopher, Anthony**
  West Hartford, CT 06107 (US)
- **HATALA, Robert, William**
  South Windsor, CT 06074 (US)

(74) Representative: **Leckey, David Herbert et al**
Frank B. Dehn & Co.
St Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

(56) References cited:

JP-A- 53 016 663	**US-A- 4 284 124**
US-A- 4 437 913	**US-A- 4 512 383**
US-A- 5 120 373	**US-A- 5 130 087**
US-A- 5 154 884	**US-A- 5 182 080**
US-A- 5 399 313	**US-A- 5 897 718**
US-A- 5 938 863	

- **MA ET AL: "Investigation of microstructure of fine grain cast IN718 compressor blade from abroad" STN CAPLUS, XX, XX, vol. 128, no. 12, 23 March 1998 (1998-03-23), XP002136723**

EP 1 153 151 B1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The present invention relates to a method of die casting Waspaloy. Nickel base superalloys such as Waspaloy typically have high melting temperatures, in excess of 2300 - 2500°F/1260-1370°C.

[0002] Nickel base and cobalt base superalloys are employed in applications which require high strength-weight ratios, corrosion resistance and use up to relatively high temperatures, e.g., up to and above about 1500 °F/ 815 °C. As used herein, superalloys generally refer to those materials characterized by high strength and which maintain high strength at high temperatures. Such materials are also characterized by relatively high melting points.

[0003] In gas turbine engines for example, these superalloys are typically employed in the turbine section, and sometimes in the latter stages of the compressor section of the engine, including but not limited to airfoils such as blades and vanes, as well as static and structural components such as intermediate and compressor cases, compressor disks, turbine cases and turbine disks. A typical nickel base superalloy utilized in gas turbine engines is sold under the name Waspaloy, and is disclosed for example in U.S. Pat. Nos. 4,574,015 and 5,120,373.

[0004] For purposes of using Waspaloy for articles such as blades and vanes in gas turbine engines, such articles at least meet the requirements set forth in Aerospace Material Specification AMS 5707 (Rev. H, publ. Aug. 1994), published by SAE Int'l of Warrendale, PA.

[0005] Gatorized Waspaloy is an advanced Waspaloy composition developed to provide improved strength and temperature capability over conventional Waspaloy. See, U.S. Pat. Nos. 4,574,015 and 5,120,373. It has a general composition, in weight percent of Chromium 15 .00 - 17 .00, Cobalt 12 .00 - 15.00, Molybdenum 3.45 - 4.85, Titanium 4.45 - 4.75, Aluminum 2.00 - 2.40. Gator Waspaloy may also small amounts of other elements such as Zirconium 0.02 - 0.12, Boron 0.003 - 0.010, and Magnesium 0.0010 - 0.005.

[0006] In the gas turbine engine industry, forging is used to produce parts having complex, three-dimensional shapes such as blades and vanes. Many nickel base superalloys, cobalt base superalloys and iron base superalloys have traditionally been precision forged to produce parts having a fine average grain size and a balance of high strength, low weight, and good high cycle fatigue resistance. However, for some applications such as turbine blades and vanes, the production of components is typically conducted using investment casting processes. Casting has been extensively used to produce relatively near-finished-shape articles.

[0007] Investment casting, in which molten metal is poured into a ceramic shell having a cavity in the shape of the article to be cast, can be used to produce such articles. However, investment casting produces extremely large grains, e.g., ASTM 0 or larger (relative to the small average grain size achievable by forging), and in some cases the entire part comprises a single grain. Moreover, since an individual mold is produced for each part, this process is expensive. Reproducibility of very precise dimensions from part to part is difficult to achieve. If the material is melted, poured and/or solidified in the presence of a gas, parts may have undesirable properties such as inclusions and porosity, particularly for materials containing reactive elements such as titanium or aluminum. Spallation of the ceramic shell also contributes to the presence of inclusions and impurities.

[0008] Permanent mold casting, in which molten material is poured into a multipart, reusable mold and flows into the mold under only the force of gravity, has also been used to cast parts generally. See, e.g., U.S. Pat. No. 5,505,246 to Colvin. However, permanent mold casting has several drawbacks. For thin castings, such as airfoils, the force of gravity may be insufficient to urge the material into thinner sections, particularly so where high melting temperature materials and low superheats are employed, and accordingly the mold does not consistently fill and the parts must be scrapped. Dimensional tolerances must be relatively large, and require correspondingly more post casting work, and repeatably is difficult to achieve. Permanent mold casting also results in relatively poor surface finish, which also requires more post cast work.

[0009] Die casting, in which molten metal is injected under pressure into a re-usable die, has been used successfully in the past to form articles from materials having relatively low-melting temperatures, e.g., below about 2000°F/1093°C. As set forth, for example, in U.S. Pat. Nos. 2,932,865, 3,106,002,3,532,561 and 3,646,990, a conventional die casting machine includes a shot sleeve mounted to one (typically fixed) platen of a multiple part die, e.g., a two part die including fixed and movable platens which cooperate to define a die cavity. The shot sleeve is oriented horizontally, vertically or inclined between horizontal and vertical. The sleeve communicates with a runner of the die, and includes an opening on the sleeve through which molten metal is poured. A plunger is positioned for movement in the sleeve, and a driving mechanism moves the plunger and forces molten metal from the sleeve into the die. In a "cold chamber" type die casting machine, the shot sleeve is typically oriented horizontally and is unheated. Casting usually occurs under atmospheric conditions, i.e., the equipment is not located in a non-reactive environment such as a vacuum chamber or inert atmosphere.

[0010] The drawbacks of such machines are also discussed in U.S. Pat. Nos. 3,646,990 and 3,791,440, both to Cross, particularly in connection with the inability to use such machines to cast higher melting point materials. In conventional machines the atmosphere in the shot sleeve is not evacuated, and the plunger also forces any air from the sleeve into the die resulting in porosity of die cast articles, a condition that is both undesirable and impermissible particularly where the article is to be used in demanding applications such as aerospace components. Accordingly, in order to avoid injecting bubbles with the molten material the shot sleeve must be filled as completely as possible, or is inclined such that any air in the molten material migrates away from the die before injection. Moreover, since the shot sleeve is unheated, a skin or "can" of molten metal solidifies on the inside of the shot sleeve, and in order to move the plunger through the sleeve to inject the molten metal into the die, the plunger must overcome the resistance of the solidified metal, scraping the skin off of the sleeve and thereby "crushing the can". However, the can forms a structurally strong member, e.g., in the form of a cylinder which is supported by the sleeve, the plunger and/or associated structure for moving the plunger can be damaged or destroyed due to the resistance to plunger motion. Where the plunger is thermally distorted and fails to match the sleeve shape or the sleeve is thermally distorted altering the clearances between the sleeve and plunger, the passage of metal between plunger and sleeve ("blowback") may occur and/or bind the plunger, all of which detrimentally affects the resultant articles. See also U.S. Pat. No. 3,533,464 to Parlanti et al.

[0011] Despite extensive efforts, the conventional "cold chamber" die casting apparatus have not been used successfully to produce articles composed of high melting temperature materials, such as titanium alloys and superalloys. As used herein, superalloys generally refer to those materials characterized by high strength and which maintain high strength at high temperatures. Such materials are also characterized by relatively high melting points. Past attempts to die cast high melting temperature materials such as titanium alloys and superalloys has resulted in inoperable die casting machinery, as well as articles characterized by inferior qualities such as impurities, excessive porosity, and relatively poor strength and fatigue properties.

[0012] It is an object of the present invention to provide die cast articles composed of nickel base and cobalt base superalloys.

[0013] It is an object of the present invention to provide a method for making die cast articles composed of high melting temperature materials such as Waspaloy; in particular to make articles of relatively complex shape, such as gas turbine engine components, that are difficult if possible to forge; and to make articles that have strength, durability and fatigue resistance comparable to corresponding articles fabricated in different manners such as investment casting and forging; and in particular articles having complex, three dimensional shapes are difficult if not impossible to forge.

[0014] According to the present invention, a method of die casting an article from Waspaloy is disclosed as claimed in claim 1. The article produced thereby, for example a blade or vane for a gas turbine engine, has a microstructure with an absence of flowlines and preferably also has a fine average grain size, e.g., at least ASTM 0 or smaller. For gas turbine engine components, the average grain size is more preferably ASTM 3 or smaller.

[0015] The articles have both yield and ultimate tensile strengths at both room and elevated temperatures that are at least comparable to parts composed of the same material but produced by other methods such as forging or investment casting, as well as comparable high and low cycle fatigue properties.

[0016] Certain preferred embodiments will now be described in greater detail by way of example and with reference to the accompanying drawings, in which:

FIG. 1 is a view of a die cast article in accordance with the present invention.

FIGS. 2 and 2A is a photomicrograph illustrating the microstructure of die cast Waspaloy in accordance with the present invention.

FIGS. 3 and 4 are schematic views of a preferred die casting machine used to produce articles composed of high melting temperature materials.

FIG. 5 is a flow chart of a preferred method.

[0017] Turning now to FIG. 1, a die cast superalloy article in accordance with the present invention are indicated generally by the reference numeral 10. In the illustrated embodiment, the article includes a turbine blade 10 composed of a die cast superalloy material, used in a gas turbine engines, although the present invention is not intended to be limited to gas turbine engine components. The article includes an airfoil 12, a platform 14, and a root 16.

[0018] The articles in accordance with the present invention are preferably characterized by an absence of flow lines. It should be noted that the articles may be thermomechanically processed after casting, if desired. In other words, the die cast articles may subsequently serve as pre-forms for use in a forging operation. In order to maximize cost savings associated with the present invention, we prefer that the die cast articles be cast to near net shape, so as to minimize post-casting work and associated expense performed on the articles. The as cast articles may be heat treated to provide desired mechanical properties.

[0019] As noted above, one superalloy utilized in gas turbine engines is sold under the name Waspaloy, and is disclosed for example in U.S. Pat. Nos. 4,574,015 and 5,120,373, which are expressly incorporated by reference herein. Waspaloy is a nickel base superalloy, and broadly has a composition, in weight percent, of about 18 - 21 Cr. 3.5 - 5 Mo. 12 - 15 Co. 2.75 - 3.25 Ti. 1.2-1.6 Al, 0.01- 0.08 Zr, 0.003 - 0.010 B, balance generally Ni. The material may also include traces of other elements. FIGS. 2 and 2A are photomicrographs illustrating the microstructure of die cast Waspaloy as cast in accordance with the present invention, and after exposure to a HIP temperature of 2050 F/ 1121°C for 4 hours without pressure. As indicated, the application of a HIP temperature, without pressure, reduces segregation. Application of an appropriate pressure will reduce or eliminate the porosity.

[0020] Specimens in accordance with the present invention are die cast, and then HIP'd. The specimens to be used for gas turbine engine are preferably also solution, stabilization and/or precipitation heat treated in a protective atmosphere.

[0021] Articles to be used as gas turbine engine components have the following properties:

Property

[0022]

Tensile Strength, min./preferred	160 ksi/ 1.12 GPa
Yield Strength. 0.2% offset, min./pref.	110 ksi/ 770 MPa
Elongation in 4D, min.	12%
Reduction of area	12%

[0023] In addition, standard stress rupture test specimens (comprising material produced in accordance with the present invention), were tested. The specimens were maintained at about 1350 °F/ 732°C and loaded continuously, after generating an initial axial stress of between about 75 ksi/ 525 MPa. The specimens ruptured only after at least 23 hours, and with elongation after rupture of at least about 10%.

[0024] The specimens to be used for gas turbine engine components should have a min. ultimate tensile strength of at least about 100 ksi/ 700 MPa, more preferably 110 ksi/ 770 MPa; yield strength of at least about 95 ksi/ 665 MPa, more preferably 100 ksi/ 700 MPa; and elongation in 4D of at least 3%.

[0025] Turning to FIGS. 3, 4 and 5, we prefer to use a die casting machine of the type having an unheated shot sleeve ("cold chamber") to produce articles in accordance with the present invention. Generally, a charge of material is prepared (FIG. 5, step 44), and the material to be die cast is melted (step 46 - FIG. 5) in the apparatus 18. We prefer to melt the superalloy material by induction skull remelting or melting (ISR) 24, for example in a unit of the type manufactured by Consarc Corporation of Rancocas, NJ which is capable of rapidly, cleanly melting a single charge of material to be cast, e.g., up to about 25 pounds/ 12 kg of material. In ISR, material is melted in a crucible defined a plurality of metal (typically copper) fingers retained in position next to one another. The crucible is surrounded by an induction coil coupled to a power source 26. The fingers include passages for the circulation of cooling water from and to a water source (not shown), to prevent melting of the fingers. The field generated by the coil heats and melts material located in the crucible. The field also serves to agitate or stir the molten metal. A thin layer of the material freezes on the crucible wall and forms the skull, thereby minimizing the ability of molten material to attack the crucible. By properly selecting the crucible and coil, and the power level and frequency applied to the coil, it is possible to urge the molten material away from the crucible, further reducing attack of the crucible wall by the molten material. By melting only a single charge rather than maintaining a large container of molten alloy, we ensure that components having relatively low melting points relative to the alloy as a whole are not vaporized and lost prior to casting.

[0026] Where reactive materials, such as titanium and aluminum and alloys containing these materials, are to be cast it is important to melt the materials in a non-reactive environment, to prevent reaction, contamination or other condition which might detrimentally affect the quality of the resulting articles. Since any gasses in the melting environment may become entrapped in the molten material and result in excess porosity in die cast articles, we prefer to melt the material in a vacuum environment rather than.in an inert environment, e.g., argon. More preferably the material is melted in a melt chamber 20 coupled to a vacuum source 22 in which the chamber is maintained at a pressure of less than 100 μ/ 13,33 Pa preferably less than 50 μ/6,665 Pa.

[0027] While we prefer to melt single, or smaller charges of material using an ISR unit, the material may be melted in other manners, such as by vacuum induction melting (VIM) and electron beam melting, so long as the material being melted is not significantly contaminated. Moreover, we do not rule out melting bulk material, e.g., several charges of material at once, in a vacuum environment and then transferring single charges of molten material into the shot sleeve for injection into the die. However, since the material is melted in a vacuum, any equipment used to transfer the molten material must typically be capable of withstanding high temperatures and be positioned in the vacuum chamber, and consequently the chamber must be relatively large. The additional equipment adds cost, and the correspondingly large vacuum chamber takes longer to evacuate thus affecting the cycle time.

[0028] Since some amount of time will necessarily elapse between material melting and injection of the molten material into the die, the material is melted with a limited superheat - high enough to ensure that the material remains at least substantially molten until it is injected, but low enough to ensure that rapid solidification occurs upon injection enabling formation of small grains and also to minimize the thermal load upon the die casting apparatus (particularly those portions of the apparatus which come into contact with the molten metal). We have melted superalloy material to a controlled, limited superheat, e.g., we have successfully used superheats within about 100° F to 200° F/55-11 °C above the melting temperature of the alloy and more preferably within about 50° F to 100° F/28-55°C, preferably using a ceramic free melting system such as an inducto-skull melting unit. The material is sufficiently superheated to ensure that it remains molten until injected into the mold, but the amount of superheat is low enough to enable rapid solidification of the molten material after injection. Molten alloy is then transferred to a horizontal shot sleeve of the machine, which is preferably located in a vacuum environment and the molten material is injected under pressure into a reusable mold. We have found that the process of pouring and injecting the molten material in one or two seconds works well in a die casting machine having an unheated shot sleeve.

[0029] In order to transfer molten material from the crucible to a shot sleeve 30 of the apparatus (step 48 - FIG 5), the crucible is mounted for translation (arrow 31 in FIG. 4), and also for pivotal movement (arrow 33 of FIG. 3) about a pouring axis, and in turn is mounted to a motor (not shown) for rotating the crucible to pour molten material from the crucible through a pour hole 32 of the shot sleeve 30. Translation of the crucible occurs between the melt chamber 20 in which material is melted and a position in a separate vacuum chamber 34 in which the shot sleeve is located. The pour chamber 34 is also maintained as a non-reactive environment, preferably a vacuum environment with a pressure level less than 100 μ/13,33 Pa and more preferably less than 50 μ/6,665 Pa. The melt chamber 20 and pour chamber 34 are separated by a gate valve or other suitable means (not shown) to minimize the loss of vacuum in the event that one chamber is exposed to atmosphere. e.g., to gain access to a component in the particular chamber. While the illustrated embodiment includes separate melting and pouring chambers, it is also possible to perform melting and pouring in a single chamber. We prefer to use separate chambers in order to minimize the loss of vacuum environment in the event that a given component must be exposed to atmosphere, e.g., to service the melting unit or the shot sleeve or to remove a casting.

[0030] As noted above, the molten material is transferred from the crucible 24 into the shot sleeve 30 through a pour hole 34. The shot sleeve 30 is coupled to a multipart, reusable die 36, which defines a die cavity 38 A sufficient amount of molten material is poured into the shot sleeve to fill the die cavity, which may include one part or more than one part. We have successfully cast as many as 12 parts in a single shot, e.g., using a 12 cavity die.

[0031] The illustrated die 36 includes two sections, 36a, 36b (but may include more sections), which cooperate to define the die cavity 38, for example in the form of a compressor blade or vane for a gas turbine engine. The die 36 is also preferably coupled directly to the vacuum source and also through the shot sleeve, to enable evacuation of the die prior to injection of the molten metal. The die may be located in a vacuum chamber, instead of or in addition to being coupled directly to a vacuum source. One section of the two sections 36a, 36b of the die is typically fixed, while the other part is movable relative to the one section, for example by a hydraulic assembly (not shown). The die preferably includes ejector pins (not shown) to facilitate ejecting solidified material from the die. The die may also include a stripper mechanism (not shown) for removing casting material from the die while the material is still hot, to further reduce thermal loads on the die.

[0032] The die may be composed of various materials, and should have good thermal conductivity, and be relatively resistant to erosion and chemical attack from injection of the molten material. A comprehensive list of possible materials would be quite large, and includes materials such as metals, ceramics, graphite, ceramic matrix composites and metal matrix composites. Each of various die material has attributes, e.g., ease of machining, strength at elevated temperatures and compromises of the two, that makes it desirable for different applications. For superalloys, we currently prefer to use dies composed of mild carbon steel, e.g., 1018, due to its low cost and ease of machining. Coatings and surface treatments may be employed to enhance apparatus performance and the quality of resulting parts. The die may also be attached to a source of coolant such as water or a source of heat such as oil (not shown) to thermally manage the die temperature during operation. In addition, a die lubricant may be applied to one or more selected parts of the die and the die casting apparatus. Any lubricant should generally improve the quality of resultant cast articles, and more specifically should be resistant to thermal breakdown, so as not to contaminate the material being injected.

[0033] Molten metal is then transferred from the crucible to the shot sleeve. A sufficient amount of molten metal is poured into the shot sleeve to partially fill the sleeve, and subsequently to fill the die. Preferably, the sleeve is less than 50% filled, more preferably less than about 40% filled, and most preferably less than 30% filled.

[0034] An injection device, such as a plunger 40 cooperates with the shot sleeve 30 and hydraulics or other suitable assembly (not shown) drive the plunger in the direction of arrow 42, to move the plunger between the position illustrated by the solid lines and the position indicated by dashed lines, and thereby inject the molten material under pressure from the sleeve 30 into the die cavity 38 (step 50 - FIG. 4). In the position illustrated by solid lines, the plunger and sleeve cooperate to define a volume that is substantially greater than the amount of molten material that will be injected. Preferably, the volume is at least twice the volume of material to be injected, more preferably at least three times. Accordingly, the volume of molten material transferred from the crucible to the sleeve fills less than one half and most preferably less than about one third of the sleeve volume. Since the sleeve is only partially filled, any material or skin that solidifies on the sleeve forms only a partial cylinder, e.g., an open arcuate surface, and is easily scraped or crushed during metal injection, and reincorporated into the molten material. For injection, we have used plunger speeds of between about 30 inches per second (ips) 0.76 m/s and 300 ips 7.62 m/s, (with a shot sleeve having an inner diameter of about 3 inches (76mm)), and currently prefer to use a plunger speed of between about 50 - 175 inches per second (ips)/ 1.28 - 4.5 m/s. The plunger is typically moved at a pressure of at least 1200 psi/ 8.4 MPa , and more preferably at least 1500 psi/ 10.5 MPa. As the plunger approaches the ends of its stroke when the die cavity is filled, it begins to transfer pressure to the metal. It may then be desirable to intensify the pressure to ensure complete filling of the mold cavity, the particular intensification parameters will depend upon the desired result. Intensification is performed to minimize porosity, and to reduce or eliminate any material shrinkage during cooling. We have used intensification above 1500 psi/10.5 MPa with satisfactory results. After a sufficient period of time has elapsed to ensure solidification of the material in the die, the ejector pins (not shown) are actuated to eject parts from the die (step 52 - FIG. 5).

[0035] As is known in the art, cast articles typically include some porosity, generally up to a few percent. Accordingly, and particularly where such articles are used in more demanding applications, such as compressor airfoils for gas turbine engines, there is a need to reduce and preferably eliminate porosity and otherwise treated as needed (step 54 - FIG. 5). The parts are therefore preferably hot isostatically pressed (HIP'd) as described above to reduce and substantially eliminate porosity in the as cast parts. Actual heat treatment and HIP parameters may be varied depending upon the desired application for the article and target cycle time for the process, however the temperature, pressure and time used during HIP must be sufficient to eliminate substantially all porosity in the cast articles, but not to allow significant grain growth. Typical grain sizes are smaller than ASTM 0, with more demanding parts such as gas turbine engine components preferably being ASTM 3 or smaller.

[0036] The parts are inspected (step 56 - FIG. 5) using conventional inspection techniques, e.g., by fluorescent penetrant inspection (FPI), radiographic, visual, and after passing inspection may be used or further treated/re-treated if necessary (step 58 - FIG. 5).

[0037] As a result of our work with superalloys, we believe that several conditions are important to produce good quality castings. The melting, pouring and injection of material, particularly for reactive materials, must be performed in a non-reactive environment, and we prefer to perform these operations in a vacuum environment maintained at a pressure preferably less than 100 μ/13,33 Pa and more preferably less than 50 μ/6.665 Pa. The amount of superheat should be sufficient to ensure that the material remains substantially and completely molten from the time it is poured until it is injected, but also to enable rapid cooling and formation of small grains once injected. Due to the relatively low superheat, molten metal transfer and injection must be rapid enough to occur prior to metal solidification. The resulting microstructure such as grain size appears to correspond to the sectional thickness of the part being cast as well as the die materials utilized and the superheat used. i.e., thinner sections tend to include smaller grains and thicker sections (particularly internal portions of thicker sections) tend to include larger grains. Higher thermal conductivity die materials result in articles having smaller grains, as does use of lower superheats. We believe that this results from relative cooling rates. The rate at which the plunger is moved, and correspondingly the rate at which material is injected into the mold appears to affect the surface finish of the articles as cast, although the design of the gating as well as the die material may also play a role in combination with the injection rate.

[0038] Die casting provides other significant advantages over forging. From the standpoint of required equipment, forging requires the production of multiple dies to make a new part, at significant cost. In contrast, only a single die set is required per part, at significantly reduced expense relative to forging. The time required to produce a part, from ingot to finished part, is reduced significantly, since there is no need to prepare specially tailored billets of material, and casting broadly is performed in a single step, as opposed to multiple forging operations. In die casting, multiple parts can be produced in a single casting. Die casting enables production of parts having more complex three dimensional shapes, thereby enabling new software design technology to be applied to and exploited in areas such as gas turbine engines and enabling production of more efficient airfoils and other components. We believe that die casting will enable the production of articles having complex shapes utilizing materials that are difficult or impossible to forge into those shapes. Moreover, die cast parts can be produced nearer to their finished shape, and with a superior surface finish, which minimizes post forming finishing operations, all of which also reduces the cost of producing such parts.

Claims

1. A method of making an article composed of Waspaloy comprising the steps of:

a) preparing a charge of material which is composed, in weight percent of 18-21 Cr, 3.5-5 Mo, 12-15 Co, 2.75-3.25 Ti, 1.2-1.6 Al, 0.01-0.08 Zr, 0.003-0.010B, balance Ni and incidental impurities,
b) melting the charge of material under a vacuum environment maintained at a pressure of less than 100μ (13.33 in a ceramic free melting system and heating the charge of material to a limited superheat within 200°F (111 °C) above the melting temperature of the alloy,

c) pouring the molten charge of material into a shot sleeve of a die casting machine under the vacuum environment so that the molten material fills less than one half of the shot sleeve; and
d) injecting the molten material under pressure into a reusable mold.

2. A method as claimed in claim 1, wherein the volume of molten material transferred to the shot sleeve fills less than one third of the volume of the shot sleeve.

3. A method as claimed in claim 1 or 2 wherein the shot sleeve is unheated.

4. A method as claimed in claim 1, 2 or 3, wherein an inducto-skull melting unit is used to melt the charge of material.

5. A method as claimed in any preceding claim, wherein the process of pouring and injecting the molten material is performed in less than two seconds.

6. A method as claimed in any preceding claim, wherein the shot sleeve is horizontal.

7. A method as claimed in any preceding claim, wherein the vacuum environment is less than 50 μ (6.665 Pa).

8. A method as claimed in any preceding claim, wherein the limited superheat is within 50°F to 100°F (27.7 to 55.5°C) above the melting temperature of the alloy.

9. A method as claimed in any preceding claim, wherein the article being made is a gas turbine engine component.

Patentansprüche

1. Verfahren zur Herstellung eines aus Waspaloy gebildeten Gegenstands, aufweisend die folgenden Schritte:

a) Bereitstellen einer Charge eines Materials, welches in Gew.-% aus 18 bis 21 Cr, 3,5 bis 5 Mo, 12 bis 15 Co, 2,75 bis 3,25 Ti, 1,2 bis 1,6 Al, 0,01 bis 0,08 Zr, 0,003 bis 0,010 B, Rest Ni und zufälligen Verunreinigungen besteht;
b) Schmelzen der Charge des Materials in einer Vakuumumgebung, die bei einem Druck von weniger als 100 μ (13,33 Pa) gehalten wird, in einem Keramik-freien Schmelzsystem und erwärmen der Charge des Materials auf eine begrenzte Überhitze innerhalb von 200 °F (111 °C) über der Schmelztemperatur der Legierung;
c) Giessen der geschmolzenen Charge des Materials in eine Schussbüchse eines Druckgussapparats in der Vakuumumgebung, so dass das geschmolzene Material weniger als die Hälfte der Schussbüchse füllt; und
d) Einspritzen des geschmolzenen Materials unter Druck in eine wiederverwendbare Form.

2. Verfahren nach Anspruch 1, bei welchem das Volumen des in die Schussbüchse gebrachten geschmolzenen Materials weniger als ein Drittel des Volumens der Schussbüchse füllt.

3. Verfahren nach einem der Ansprüche 1 oder 2, bei welchem die Schussbüchse nicht beheizt ist.

4. Verfahren nach einem der Ansprüche 1, 2 oder 3, bei welchem eine Induktionsschalen-Schmelzeinrichtung verwendet wird, um die Charge des Materials zu schmelzen.

5. Verfahren nach einem der vorangehenden Ansprüche, bei welchem der Prozess des Giessens und Einspritzens in weniger als zwei Sekunden durchgeführt wird.

6. Verfahren nach einem der vorangehenden Ansprüche, bei welchem die Schussbüchse horizontal ist.

7. Verfahren nach einem der vorangehenden Ansprüche, bei welchem die Vakuumumgebung weniger als 50 μ (6,665 Pa) ist.

8. Verfahren nach einem der vorangehenden Ansprüche, bei welchem die begrenzte Überhitze innerhalb von 50 bis 100 °F (27,7 bis 55,5 °C) über der Schmelztemperatur der Legierung ist.

9. Verfahren nach einem der vorangehenden Ansprüche, bei welchem der Gegenstand, der hergestellt wird, ein Gasturbinenmaschinenbauteil ist.

Revendications

1. Procédé de fabrication d'un article composé de Waspaloy comprenant les étapes consistant à :

   a) préparer une charge de matériau qui se compose, en pourcentage en poids, de 18 - 21 Cr, 3,5 - 5 Mo, 12 - 15 Co, 2,75 - 3,25 Ti, 1,2 -1,6 Al, 0,01 - 0,08 Zr, 0,003 - 0,010 B, le reste étant Ni et des impuretés accidentelles ;
   b) faire fondre la charge de matériau sous un environnement de vide maintenu à une pression de moins de 100 μ (13,33 Pa) dans un système de fusion sans céramique, et chauffer la charge de matériau à une surchauffe limitée de l'ordre de 111 °C (200°F) au-dessus de la température de fusion de l'alliage ;
   c) verser la charge de matériau fondue dans un manchon d'injection d'une machine à couler sous pression sous l'environnement de vide de façon que le matériau fondu remplisse moins que la moitié du manchon d'injection ; et
   d) injecter le matériau fondu sous pression dans un moule réutilisable.

2. Procédé selon la revendication 1, dans lequel le volume de matériau fondu transféré dans le manchon d'injection remplit moins d'un tiers du volume du manchon d'injection.

3. Procédé selon la revendication 1 ou 2, dans lequel le manchon d'injection n'est pas chauffé.

4. Procédé selon la revendication 1, 2 ou 3, dans lequel une unité de fusion à peau induite est utilisée pour faire fondre la charge de matériau.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel le processus consistant à verser et à injecter le matériau fondu est réalisé en moins de deux secondes.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel le manchon d'injection est horizontal.

7. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'environnement de vide est inférieur à 50 μ (6,665 Pa).

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel la température de surchauffe limitée est comprise entre 27,7°C et 55,5°C (entre 50°F et 100°F) au-dessus de la température de fusion de l'alliage.

9. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'article en cours de fabrication est un composant de moteur de turbine à gaz.

FIG.1

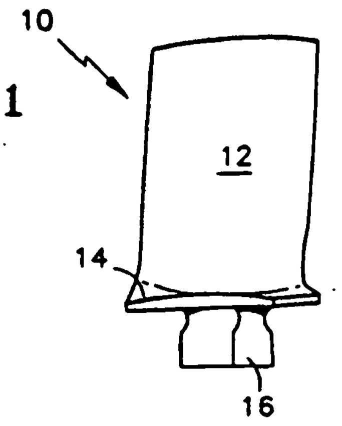
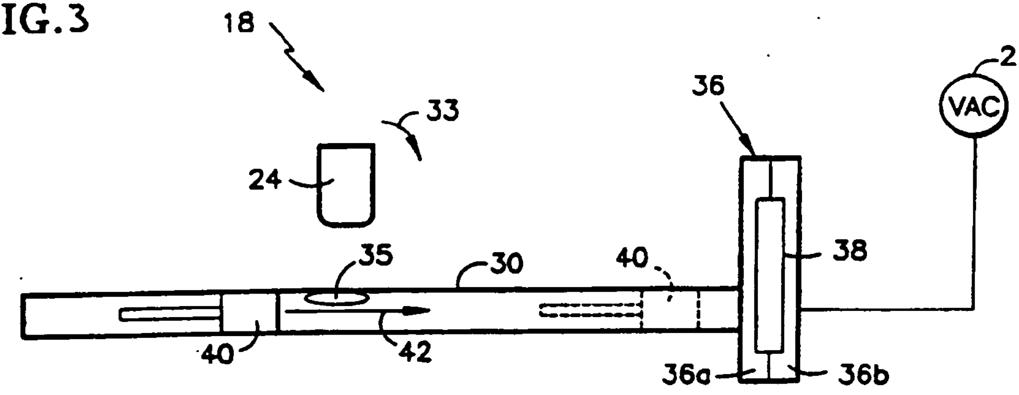


FIG.3



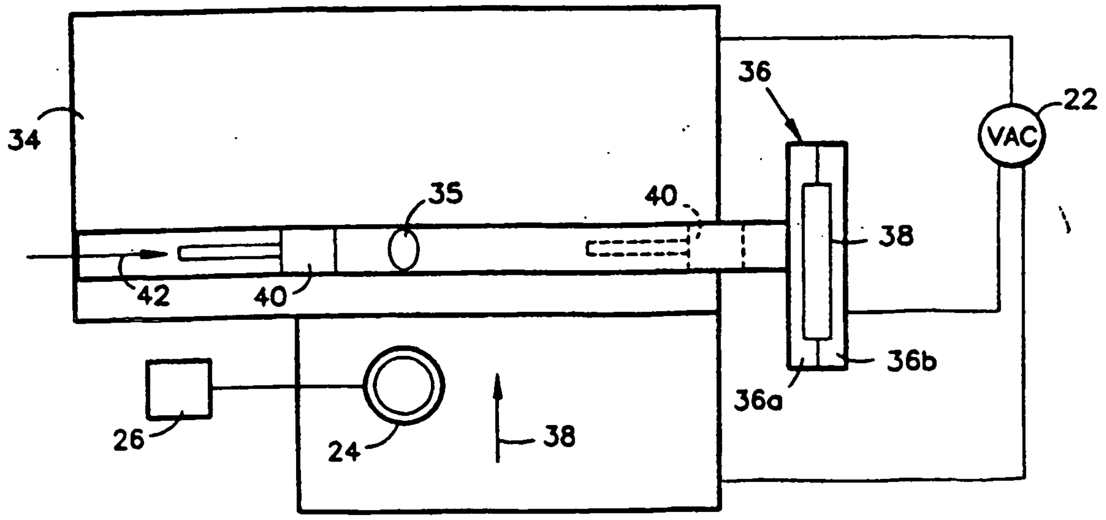


FIG.4

FIG. 2

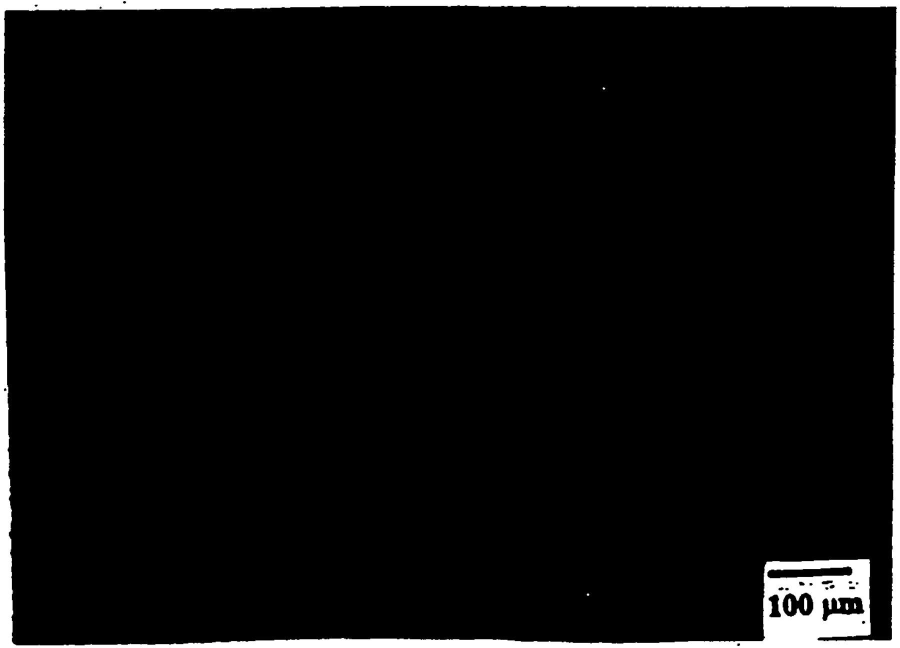
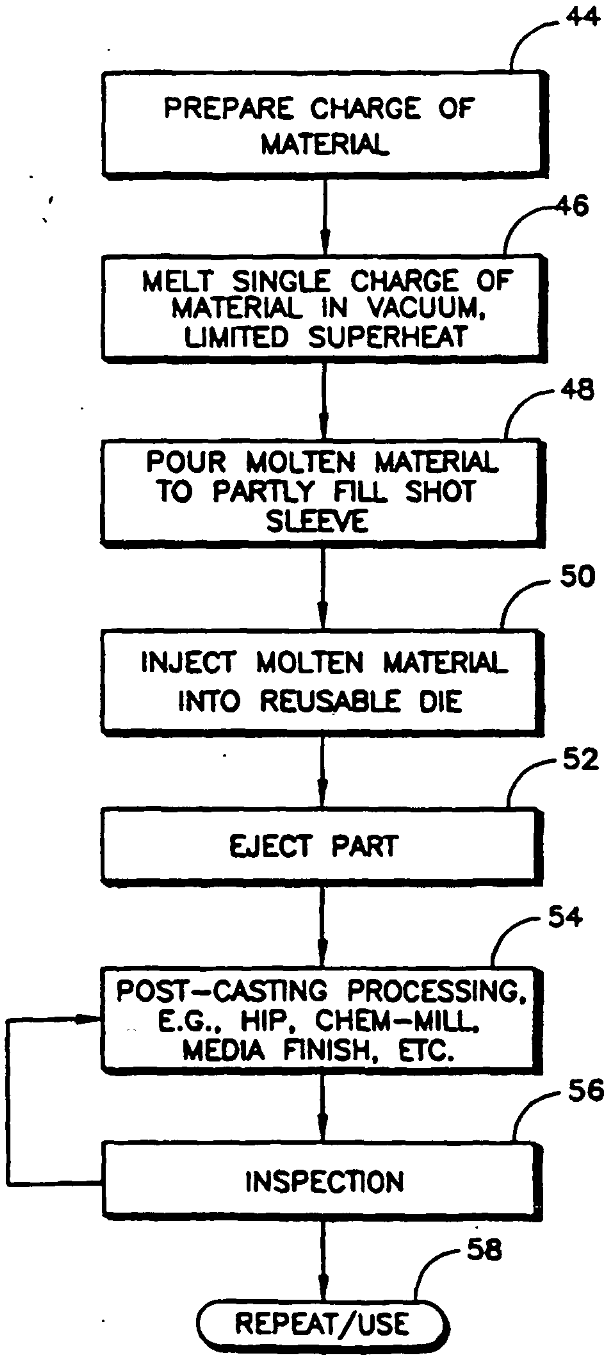


FIG. 2A

FIG. 5


44
PREPARE CHARGE OF MATERIAL
46
MELT SINGLE CHARGE OF MATERIAL IN VACUUM, LIMITED SUPERHEAT
48
POUR MOLTEN MATERIAL TO PARTLY FILL SHOT SLEEVE
50
INJECT MOLTEN MATERIAL INTO REUSABLE DIE
52
EJECT PART
54
POST-CASTING PROCESSING, E.G., HIP, CHEM-MILL, MEDIA FINISH, ETC.
56
INSPECTION
58
REPEAT/USE