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

(11) EP 2 564 956 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
06.03.2013 Bulletin 2013/10

(51) Int Cl.:
B22F 3/22 *(2006.01)* ***C22C 33/02*** *(2006.01)*

(21) Application number: **12185488.9**

(22) Date of filing: **30.01.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

(30) Priority: **28.06.2006 KR 20060058373**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
07708670.0 / 2 043 801

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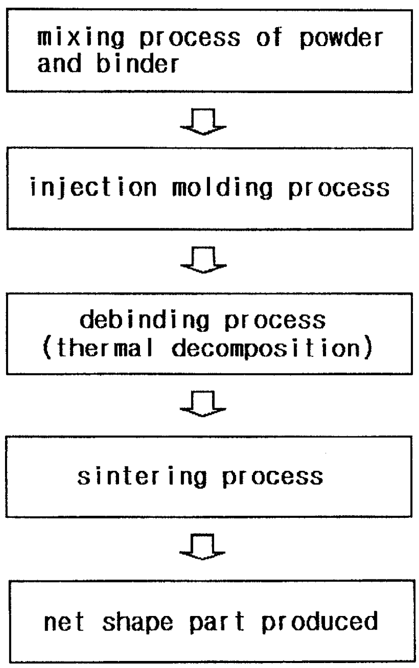
Remarks:
This application was filed on 21-09-2012 as a divisional application to the application mentioned under INID code 62.

(54) **Fabrication method of alloy parts by metal injection molding**

(57) A method of manufacturing an alloy part comprises mixing an alloy powder and a binder, the alloy powder having a composition including 40 to 50wt% Cr, 1 to 2.5wt% Si, 0.5wt% or less C, 5.6 to 6.2wt% B and the remainder Fe and unavoidable impurities; performing an injection molding on the mixture to form the injection moldings to have a shape of the part;removing the binder from the injection moldings; and sintering the injection moldings from which the binder is removed.

【Figure 1】



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Description

[Technical Field]

[0001] The present invention relates to a metal injection molding and a part manufactured by the metal injection molding, and more particularly, to a method of manufacturing a part by using Fe-Cr-based alloy powder in a metal injection molding and the part, that is, the metal injection molding and the part capable of reducing a limitation on a size of the part, increasing a productivity, and providing the part having excellent properties at a low cost as compared with a conventional manufacturing method.

[Background Art]

[0002] As a method of manufacturing precision parts having complex shapes used for cars, computers, electronic components, industrial components, medical instruments, and abrasion-resistant components, there are cutting, die casting, precision casting, and powder metallurgy, and so on. However, these methods have problems in that a manufacturing cost is high, productivity decreases, desired properties cannot be obtained due to a limitation on usable constituent materials of an alloy, and complex 3D shapes cannot be obtained, and so on.

[0003] In order to solve the problems of formability, processability, and productivity, a metal injection molding, that is, a method including a process of mixing power with a binder, a process of injection molding the mixture, a process of removing the binder from the injection moldings, and a process of sintering and forming the debinded injection moldings, thereby manufacturing a product having a net shape that hardly needs finishing processing, is known.

[0004] Parts manufactured by the metal injection molding are mainly used for high value-added precision parts such as a cellular phone hinge requiring abrasion resistance, durability, and mechanical chemical properties including corrosion resistance, high strength, high hardness, and high quality. These parts are manufactured by using iron, nickel, or stainless-based powder.

[0005] However, the iron, nickel, or stainless-based powder has problems in that the sintering process that is the last forming process is performed at a very high sintering temperature of about 1350°C and costs of electric power consumed for the sintering process and the sintering equipment are very high. In addition, when a conventional powder material is used, adequate properties may not be obtained according to applications.

[0006] Accordingly, in order to decrease the sintering temperature and increase a forming precision, a micro-powder injection molding (PIM) of significantly decreasing a size of the powder is attempted. In this method, by decreasing the size of the powder, the sintering temperature may decreases by about 100°C as compared with a conventional method. However, a powder price markedly increases as compared with the conventional method, so that there is a problem in that reducing the manufacturing cost cannot be expected.

[0007] Powder injection molding uses various materials such as metal, ceramic, and cemented carbide, and the iron-based material such as stainless that occupies more than 40% of the total materials. Particularly, STS316L has been widely applied. However, as the powder injection molded parts have gradually changed from parts based on a shape to parts as a structural material requiring mechanical properties used for airplanes, cars, medical instruments, STS630(17-4PH) having a high strength has been increasingly used. The STS630 is martensite-based precipitation-hardened alloy and is one of high strength alloys having a high corrosion resistance. However, since the stainless has a high sintering temperature, there is a problem in that cost of production significantly increases.

[Disclosure]

[Technical Problem]

[0008] In order to solve the aforementioned problems, the present invention provides a method of manufacturing parts which have a low sintering temperature, have an excellent hardness, and can be produced at a low cost to be applied to high value-added precision parts.

[Technical Solution]

[0009] According to an aspect of the present invention, there is provided a method of manufacturing an alloy part according to claim 1.

[0010] In addition, the step of sintering may be performed in a vacuum in a reducing gas or an inert gas atmosphere at a temperature of from 1100°C to less than a melting point of the alloy or at a temperature of 1150°C or more or a temperature of 1200°C or more according to a manufacturing cost and required properties. The sintering atmosphere is an atmosphere in which oxide existing at surfaces of the alloy powder is removed during the sintering process.

Preferably, the sintering atmosphere is a high-purity hydrogen atmosphere.

[0011] In addition, the sintering process is performed at a sintering temperature of from 1100°C to about 1250°C that is a melting point of the alloy powder. Accordingly, the sintering temperature can be decreased by 100 to 250°C as compared with a sintering temperature of 1350°C of stainless-based powder, so that costs of electric power and energy consumed for the sintering process can be significantly reduced.

[0012] In addition, an average particle size of the ally powder may range from 0.01 to 100μm. Powder having an average particle size of less than 0.01μm may cause an significant increase in a manufacturing cost of the powder and in a price of a product. Powder having an average particle size of more than 100μm cannot obtain an enough precision and desired properties. Therefore, the powder having the aforementioned particle size may be used.

[0013] In addition, the step of removing the binder may be performed by heating the injection moldings at a temperature of from 300 to 700°C in a reducing gas atmosphere and maintaining the temperature for 0.5 to 5 hours.

[0014] In addition, a porosity of the part manufactured by the manufacturing method may be a volume fraction of 7% or less, and more preferably, 5% or less. When the porosity exceeds 7%, hardness and properties are decreased, so that the part having the porosity of more than 7% cannot be applied.

[Advantageous Effects]

[0015] As described above, the metal parts manufactured by the metal injection molding according to the present invention have advantages in that a limitation on sizes of the parts is reduced due to characteristics of the manufacturing method, and a continuous production is possible. In addition, the metal parts have the same or more hardness as compared with metal injection moldings using conventional stainless-based alloy powder but have a lower sintering temperature. Accordingly, high quality and high value-added parts with a competitive price can be manufactured, so that the parts can be used in all fields including cars, computers, electronic components, industrial components, medical instruments, abrasion-resistant components, and so on.

[0016] In addition, according to the metal injection molding according to the present invention, pores are minimized, and near net shape products with a high density can be manufactured.

[Description of Drawings]

[0017]

FIG. 1 is a flowchart schematically showing a manufacturing process according to the present invention.

FIG. 2 is a picture taken by a scanning electron microscope (SEM) showing a degree of denseness of a metal part manufactured according to an embodiment of the present invention.

FIG. 3 is a picture taken by a SEM showing a degree of denseness of a metal part manufactured according to another embodiment of the present invention.

[0018] The present invention will now be described more fully with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. The exemplary embodiments should be considered in descriptive sense only and not for purposes of limitation.

[Mode for Invention]

[0019] Chemical compositions of alloy powder used in the current embodiments are as follows.

[Table 1]

Chemical compositions of the alloy powder										
element	Cr	Si	C	Cu	S	B	Ni	Mo	Co	Fe
C	30-32	1.0-1.8	-	2.2-2.8	-	3.5-4.5	17-19	3.5-4.5	8.8-11	Bal.
M	43-46	1.7-2.2	0.17	-	0.2	5.6-6.2	-	-	-	Bal.

[0020] As shown in Table 1 above, a metal injection molding according to the present invention uses powder having an alloy composition represented as "C" mainly including Fe, Cr, Ni, Co, or the like and an alloy composition represented as "M" mainly including Fe, Cr, B, or the like. As described above, the Cr of from 20 to 50wt% or more is mixed with the Fe, so that a sintering temperature can be significantly decreased. In addition, as shown in an experimental result below, parts having the same or better mechanical properties as compared with conventional stainless powder injection molded parts can be manufactured.

[0021] FIG. 1 shows a manufacturing process of the metal injection molding according to an embodiment of the present invention. Referring to FIG. 1, the metal injection molding includes a mixing process of powder and a binder, an injection molding process of the mixture, a debinding process of removing the binder from the injection moldings by a thermal decomposition, and a process of sintering the debinded moldings, thereby manufacturing near net shape parts.

[0022] In the mixing process, a shape of the alloy powder may be close to a spherical shape, and an average particle size of the powder may be 100μm or less for a high sintering density and a high numerical precision. In the current embodiment of the present invention, particles of 40μm or less are used.

[0023] In addition, the most important work in the mixing process is to select a suitable binder. The suitable binder is selected so that mixing and injection molding processes are easy and materials having desired properties should be obtained when the used binder is removed after the injection molding process. The binder is a material composed of two to five selected from a bonding(bodying) agent, a lubricant, a plasticizer, and a surfactant. As long as formability is guaranteed during the injection molding, it is preferable that the total amount of the binder is smaller so as to prevent deformation during the debinding and the sintering processes, and a volume fraction of the binder may range from 30% to 50%.

[0024] The binder used in the embodiment of the present invention is a mixture of ethylene vinyl acetate (EVA) of 20wt% and paraffin wax of 80wt%. The mixing process of the alloy powder and the binder includes weighing the alloy powder and the binder in a predetermined ratio and mixing the alloy powder with the binder in a sigma blade mixer at a temperature ranging from 130 to 160°C for two hours.

[0025] The injection molding process of the mixture includes feeding the alloy mixture into a metal injection molding machine of about 27 ton and injecting the alloy mixture into a metal mold having a predetermined shape at a pressure of 450 bar and a temperature of 120°C.

[0026] The debinding process of removing the binder from the injection moldings includes feeding the moldings into a tube furnace, increasing the temperature up to 300°C in a high-purity hydrogen atmosphere at a speed of 2 °C/min and maintaining the temperature for an hour, increasing the temperature up to 500°C at a speed of 3°C/min and maintaining the temperature for an hour, and increasing the temperature up to 700°C at a speed of 3°C/min and maintaining the temperature for an hour, thereby completely removing the binder.

[0027] A liquid phase transition temperature of each alloy powder having a composition shown in Table. 1 above is measured by a differential thermal analysis (DTA). The sintering process is performed in a condition described in Table 2 below at a temperature ranging from 1150°C to less than the liquid phase transition temperature.

[Table 2]

Sintering condition		
experimental condition	specimen	sintering temperature and maintaining time
1	C1	1100°C/30mim
2	C2, M2	1150°C/30mim
3	C3, M3	1200°C/30mim
4	M4	1250°C/30mim

[0028] Specimens C1, C2, and C3 shown in Table 2 have the same composition but have different sintering temperatures, and so do specimens M1, M2, and M3. The sintering process is performed by increasing the temperatures up to target temperatures of 1100° C, 1150° C, 1200° C, and 1250° C shown in Table 2 at a speed of 5° C/min and maintaining the temperatures in the high-purity hydrogen atmosphere for 30 minutes. As described above, the sintering process is performed in a reducing gas atmosphere, so that oxide layers formed at surfaces of the alloy powder are removed, and particle bonding proceeds by diffusion.

[0029] FIGS. 2 and 3 are pictures taken by a scanning electron microscope (SEM) showing microstructures of metal parts manufactured at the above sintering temperatures. As shown in FIGS. 2 and 3, as the sintering temperature increases, the volume fraction of pores formed at a grain boundary significantly decreases, and sizes of the pores tend downward. In addition, a result of measuring a porosity and a relative density, that is, a degree of denseness, is shown in following Table 3.

[Table 3]

A result of measuring a porosity and a relative density of parts		
specimen	porosity (%)	relative density (%)
C1	4.3	95.68
C2	3.5	96.47
C3	0.01	99.99
M2	0.61	99.39
M3	0.21	99.79
M4	0.05	99.95

[0030] As shown in Table 3, the C1 sintered at the temperature of 1100°C has a relative density of 95.68% that is a relatively high degree. As the sintering temperatures increases, most specimens have high relative densities of more than 99%.

[0031] By measuring a hardness of the parts according to the current embodiment, a result shown in Table 4 is obtained.

[Table 4]

A result of measuring a hardness of parts		
specimen	hardness (VHN)	note
C1	94	embodiment
C2	115	embodiment
C3	319	embodiment
M2	353	embodiment
M3	747	embodiment
M4	1059	embodiment
STS316L	97	comparative example
STS630	275	comparative example
STS440C	543	comparative example

[0032] As shown in Table 4, the C1 according to the embodiment of the present invention is sintered at a very low sintering temperature but has a similar hardness as compared with STS316L, the C2 has a better hardness, and the C3 and the M2 have about three times the hardness of the STS316L and have the same or more hardness as compared with STS630. Namely, the parts having high physical properties at a low cost as compared with the stainless powder injection moldings can be manufactured, so that the parts can replace the STS316L and the STS630.

[0033] In addition, it can be seen that the M3 and the M4 according to the present invention have lower sintering temperatures as those of the stainless powder injection moldings but have the excellent hardnesses of 747 and 1059, respectively, as compared with the stainless powder injection moldings.

[Industrial Applicability]

[0034] Present invention is applicable to the field of powder injection molding.

Claims

1. A method of manufacturing an alloy part, comprising:

mixing an alloy powder and a binder, the alloy powder having a composition including

40 to 50wt% Cr,
1 to 2.5wt% Si,
0.5wt% or less C,
5.6 to 6.2wt% B and
the remainder Fe and unavoidable impurities;

performing an injection molding on the mixture to form the injection moldings to have a shape of the part;
removing the binder from the injection moldings; and
sintering the injection moldings from which the binder is removed.

2. The method of claim 1, wherein the step of sintering is performed in a vacuum in a reducing gas or an inert gas atmosphere at a temperature of from 1100°C to less than a melting point of the alloy.

3. The method of claim 2, wherein the sintering temperature ranges from 1150°C to less than the melting point of the alloy.

4. The method of claim 1, wherein an average size of the alloy powder ranges from 0.01 to 100μm.

5. The method of claim 1, wherein the step of removing the binder is performed by heating the injection moldings at a temperature of from 300 to 700°C in a reducing gas, an inert gas, or a mixture of the reducing gas and the inert gas atmosphere and maintaining the temperature for 0.5 to 5 hours.

6. An alloy part manufactured through a method comprising:

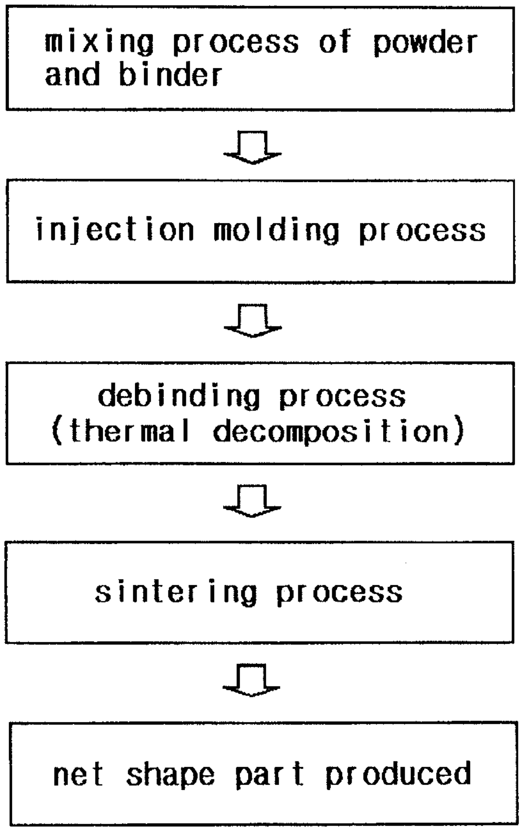
mixing an alloy powder and a binder, the alloy powder having a composition including

40 to 50wt% Cr,
1 to 2.5wt% Si,
0.5wt% or less C,
5.6 to 6.2wt% B and
the remainder Fe and unavoidable impurities;

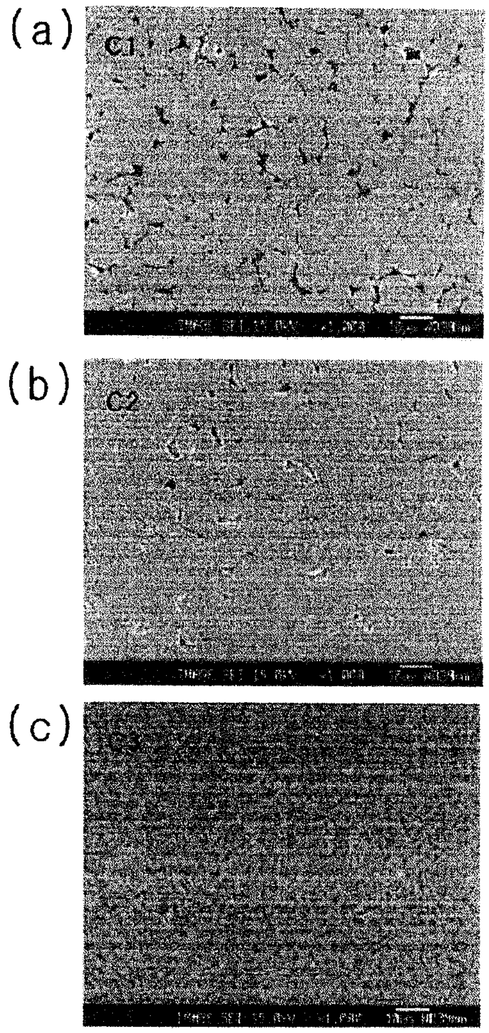
performing an injection molding on the mixture to form the injection moldings to have a shape of the part;
removing the binder from the injection moldings; and
sintering the injection moldings from which the binder is removed.

7. The alloy part of any one of claims 6, wherein a porosity of the part is a volume fraction of 7% or less.

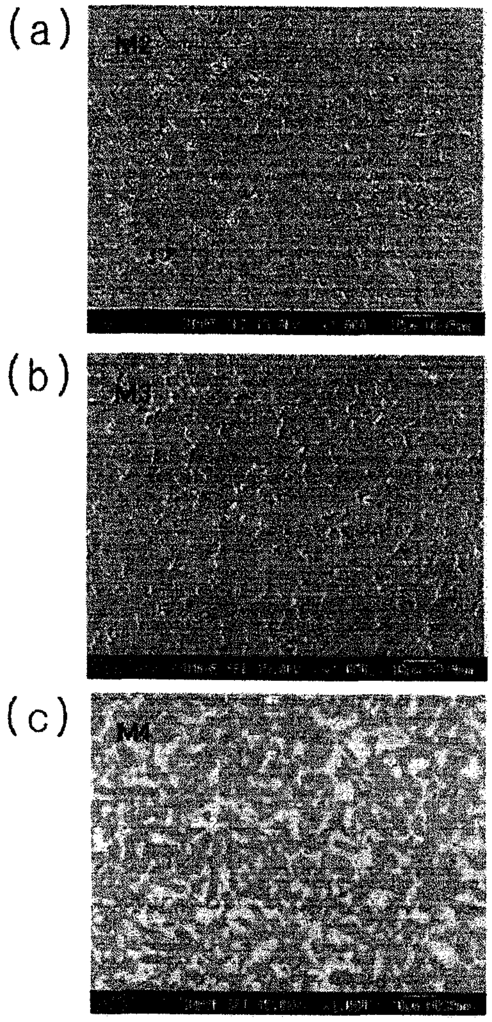
【Figure 1】


mixing process of powder and binder
injection molding process
debinding process (thermal decomposition)
sintering process
net shape part produced

【Figure 2】



【Figure 3】



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EUROPEAN SEARCH REPORT

Application Number
EP 12 18 5488

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 1 033 194 A1 (INJEX CORP [JP]) 6 September 2000 (2000-09-06) * claims 1-13; figures 1-3; example 7; table 1 * -----	1-7	INV. B22F3/22 C22C33/02
A	US 4 721 599 A (NAKAMURA HIDEKI [JP]) 26 January 1988 (1988-01-26) * example 6 * -----	1-7	
A	US 6 309 592 B1 (WANG TA-HSIANG [TW] ET AL) 30 October 2001 (2001-10-30) * column 2, line 60 - line 63; figure 4 * * column 3, line 26 - line 45 * -----	1-7	
A	US 6 299 664 B1 (MATSUMOTO OSAMU [JP] ET AL) 9 October 2001 (2001-10-09) * column 3, line 44 - line 53 * * claim 1; figure 1 * -----	1-7	

TECHNICAL FIELDS SEARCHED (IPC)

B22F
C22C

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	22 January 2013	Liu, Yonghe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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