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(54) METHOD OF MANUFACTURING VARIABLE VANE

(57) The present invention provides a variable vane manufacturing method capable of setting the dimensions of a shaft unit and a blade unit with desired dimensional precisions without any machining. A sinter is prepared such that the height of a blade unit 2 ranges within +0.3% to +0.9%, the thickness of the blade unit 2 ranges within - 0.6% to -0.0%, the diameter of a shaft unit 3 ranges within +0.3% to +0.9%, the length from the lower end of the blade unit 2 to the lower end of the shaft unit 3 ranges within - 0-6% to -0.0% with respect to the target dimensions of a final product, and a sintering density is 95% or more of a relative density. The height and thickness of the blade unit 2 in the sinter are set to desired product dimensions in a first pressing process at the same time; the coaxiality between the blade unit 2 and the shaft unit 3 is set to a desired product dimension in a second pressing process; and the roundness of the shaft unit 3 is set to a desired product dimension in a third pressing process.

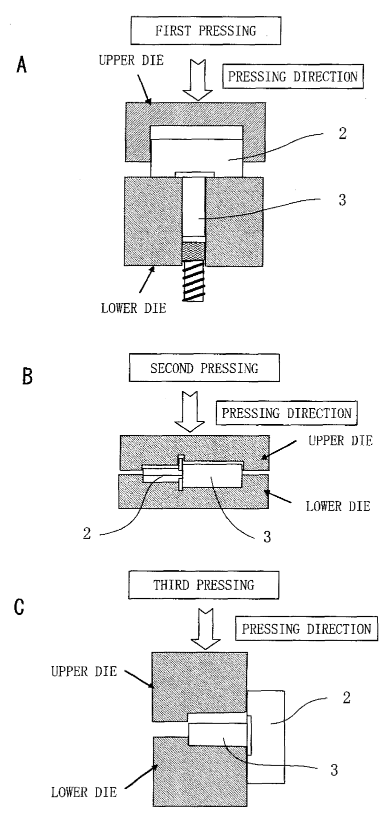

FIG. 4

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Description

Technical Field

[0001] The present invention relates to a method for manufacturing a variable vane to be incorporated in a turbocharger for use in an automobile engine or the like. More particularly, the present invention relates to a method for fabricating a variable vane, in which a sinter obtained by metal powder injection molding (i.e., an MIM method) is pressed with a die for correcting the height and thickness of a blade, a die for correcting the shape of the blade, and a die for correcting a shaft so that both of the blade and the shaft can be formed in predetermined dimensions without machining.

Background Art

[0002] A turbocharger for use in an automobile engine or the like is designed such that the flow rate of exhaust gas is amplified so as to enable the engine to efficiently obtain an output even during a low-speed rotation, the rotation of a turbine on an exhaust side by using the resultant exhaust energy enables a turbine on an intake side connected directly to the turbine on the exhaust side to be rotated, so as to forcibly take air into the engine. The turbocharger is provided with a plurality of variable vanes as parts for adjusting the flow amount and flow rate of the exhaust gas.
Each of the variable vanes includes a rotational center shaft and a blade for adjusting the flow amount and flow rate of the exhaust gas. The blade is more reduced in thickness toward its tip.

[0003] The above-described variable vane has been conventionally fabricated by machining. However, this method requires a very long machining time. Only about 100 to 500 variable vanes can be fabricated by one machine per day. It has resulted in very poor efficiency.

[0004] In view of this, several fabricating methods have been proposed. Patent Literature 1 discloses a product fabricating method by cold forging and polishing a steel material. Moreover, Patent Literature 2 discloses a product fabricating method for, by using a material fabricated by lost wax or the MIM method, rolling the material to form a shaft whereas pressing the material in a height direction to form a blade. Additionally, Patent Literature 3 discloses a product fabricating method for polishing a shaft by using a sinter obtained by the MIM method.

[0005] The method disclosed in Patent Literature 1 requires forging and polishing, and therefore, a stainless alloy plate is prepared as the material. However, there are limitations on an improvement in production rate during mass production and cost reduction from the viewpoints of a post-machining time and effective use of a material. In the case of a thin product having a complicated shape, it is difficult to forge it into a desired shape.

[0006] In the method disclosed in Patent Literature 2, a product is fabricated by pressing and rolling a material obtained by lost wax or the MIM method. However, the method disclosed in Patent Literature 2 does not refer to a material machining method, and therefore, post machining is inevitably required in an axial rolling process. Precision in a height direction can be enhanced by single-shaft pressing from above. In particular, in the conventional MIM method, dimensional variations and deformation of $\pm 0.5\%$ or more with respect to a product dimension are generated during debinding (degreasing) and sintering. Therefore, even if the dimensional precision of the product is enhanced in the height direction by pressing, it is difficult to correct deformation in a vane unit. As a consequence, many portions need be cut and polished-Specifically, in the case where the height of a blade unit is 10 mm, the dimensional variation of a product obtained by the conventional MIM method is ± 0.05 mm. However, there is a deformation of about ± 0.05 mm also in the width direction of the blade unit. Therefore, even if the desired dimension in the height direction can be achieved by pressing, the blade unit is likely to be expanded by compression in the width direction (i.e., a thickness direction) of the blade unit when pressed. Consequently, a blade unit having the height and width as calculated cannot be obtained unless the sinter is excellent in dimensional precision not only in the height direction but also in the width direction. Also as for the coaxiality between the blade unit and a shaft, variations of coaxiality of about $\pm$0-05 mm are generated in the sinter obtained by the conventional MIM method. As a consequence, even if the dimensional precision of the shaft by machining and pressing can fall within allowable dimensions, the blade unit need be machined such that the coaxiality can fall within 0.01 mm or less.

[0007] Likewise, Patent Literature 3 does not refer to machining by the MIM method. Finally, polishing is inevitable for enhancing the precision of the squareness of a shaft unit to a polished vane unit. In addition, in the case where torsion or warpage occurs at the blade unit, it is difficult to obtain a highly precise product only by pressing.

Prior Art Technical Literature

Patent Literature

[0008]

Patent Literature 1: Japanese Patent No. 3833002
Patent Literature 2: Japanese Patent No. 3944819
Patent Literature 3: Japanese Laid-Open Patent Publication No. 2008-88849

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0009] In view of the above, an object of the present invention is to provide a method capable of manufacturing a variable vane having a high dimensional precision only by pressing without machining in order to solve the above-described problems.

MEANS FOR SOLVING THE PROBLEMS

[0010] The inventors of the present invention earnestly studied in order to solve the above-described problems. As a result, a sinter having a shape approximate to that of a final product and the predetermined relationship with a desired final product is prepared. The height and thickness (i.e., width) of the blade unit in the sinter are set to desired product dimensions at the same time in a first pressing process; the coaxiality between the blade unit and the shaft unit is set to a desired product dimension in a second pressing process; and the roundness(out-of-roundness) of the shaft unit is set to a desired product dimension in a third pressing process. As a consequence, the dimensions of the shaft unit and the blade unit can be set with the dimensional precision (i.e., $\pm$0.01 mm to 0.05 mm or less of a target dimension) without machining, thereby solving the above-described problems.

[0011] Specifically, the present invention is featured by a method for manufacturing a variable vane including a planar blade unit and a columnar shaft unit positioned under the blade unit, the method comprising the step of:

pressing a sinter having a shape approximate to that of a desired final product;
wherein the sinter is integrally constituted of the blade unit and the shaft unit, and has the height of the blade unit within +0.3% to +0.9%, the thickness of the blade unit within -0.6% to -0.0%, the diameter of the shaft unit within +0.3% to +0.9%, the length from the lower end of the blade unit to the lower end of the shaft unit within -0.6% to -0.0% with respect to the target dimensions of the final product, and a sintering density of 95% or more of a relative density; and
wherein the pressing process includes three processes:

- in a first pressing process, the sinter is pressed with a lower die having a shaft unit insertion hole and an upper die having a shape except a lower end surface of the blade unit, so as to adjust the height and thickness of the blade unit;
- in a second pressing process, the blade unit and shaft unit of the sinter are pressed at the same time with an upper die and a lower die, each of which has a shape obtained by dividing the variable vane at a surface at which the thickness of the blade unit is bisected, so as to adjust the angle of the shaft unit with respect to the blade unit and the coaxiality of the shaft unit with respect to the blade unit; and
- in a third pressing process, the shaft unit of the sinter is pressed in a direction turned at 90˚ from that in the second pressing process with an upper die and a lower die, each of which has a semi-columnar shape corresponding to the shaft unit of the variable vane, so as to adjust the roundness of the shaft unit.

[0012] The die for use in the first pressing process includes the lower die for holding the sinter by inserting the shaft unit under the blade unit thereinto and the upper die having the shape except the lower end of the blade unit (i.e., the shapes of the blade unit in the height and thickness directions can be defined at the same time). As for the upper die, in the case where the variable vane having the shaft unit also above the blade unit is fabricated, the die has the shape including the shaft unit above the blade unit in addition of the shape of the blade unit. The upper die is pressed against the lower die, so that the blade unit is compressed at its upper surface and the blade unit is expanded and deformed at its side surface while being compressed downward, and further, the shape of the side surface conforms with the shape of the die, thus achieving the desired height of the blade unit, the shapes of the side surface and blade, and the squareness of the shaft with respect to the blade.
The die for use in the second pressing process includes the upper die and the lower die, each of which has the shape obtained by dividing the variable vane (i.e., the blade unit and the shaft unit) at the surface at which the thickness of the blade unit is bisected. The product is fixed in a lateral direction by the lower die. The upper die is compressed downward so that the blade unit and the shaft unit are pressed at the same time, thus achieving the verticality of the shaft unit with respect to the blade unit and the coaxiality of the shaft unit with respect to the blade unit.

Moreover, the die for use in the third pressing process includes the upper die and the lower die, each of which has the semi-columnar shape in conformity with the shaft unit of the variable vane. The upper and lower dies are pressed against each other in the state in which the shaft unit positioned under the blade unit of the sinter is turned at 90˚ from that in the second pressing process, thereby achieving the roundness of the shaft unit.

[0013] In the pressing, the sinter having the dimensions of the blade unit and the shaft unit within the dimensional ranges with respect to the desired dimensions of the final product is used as a sinter to be pressed. As a consequence, the dimensions of the blade unit and the shaft unit can be set with the desired dimensional precision (±0.01 mm to 0.05 mm or less of the target dimension) without machining. Moreover, the sinter having a relative density of 95% or more is used, thereby achieving the dimensional precision after the pressing within the desired dimensional precision, and further, the variable vane having mechanical strength resistant against use at high temperature can be manufactured.

[0014] It is preferable that the sinter should be a sinter having a relative density of 98%. Moreover, the first to third pressing processes may be continuously performed by using a multiple forming machine capable of pressing and bending in directions of 360˚, thus saving the energy for pressing.

[0015] In order to manufacture the sinter for use in the pressing, in a method for manufacturing the sinter including adding an organic binder (b) into metallic powder (a), followed by heating and mixing, obtaining an injection molding material by pulverizing or pelleting, preparing a molded body by injection-molding the molding material, and thermal debinding(heating/degreasing) the resultant molded body,

the metallic powder (a) is powder having an average particle diameter of 1 μm to 20 μm and a tap density of 3.5 g/m^3 or more;

the organic binder (b) contains 5 vol% to 40 vol% of polyacetal (b1) and 5 vol% to 40 vol% of polypropylene (b2); and in adding the organic binder (b) into the metallic powder (a), the organic binder (b) is added within a range of 30 vol% to 60 vol% with respect to the total amount (a+b) of the metallic powder and the organic binder, thus achieving the sinter suitable for manufacturing the variable vane.

[0016] Additionally, it is preferable that in manufacturing the sinter, the debinding should be performed at a highest temperature of 800˚C or lower in any of a reduced pressure inactive gas atmosphere, an atmospheric pressure inactive gas atmosphere, and an atmospheric pressure hydrogen atmosphere; and

the sintering should be performed at a temperature from 1000˚C or higher and 1500˚C or lower in any of a reduced pressure inactive gas atmosphere, a pressurized inactive gas atmosphere, an atmospheric pressure inactive gas atmosphere, and an atmospheric pressure hydrogen atmosphere.

[0017] In addition, it is preferable that in the sinter manufacturing process, a primary sinter having a relative density of 94% or more should be manufactured, and then a sinter having a relative density of 98% or more should be manufactured by hot isotropic pressuring.

EFFECTS OF THE INVENTION

[0018] According to the present invention, it is possible to manufacture the variable vane having the high dimensional precision only by pressing the sinter without machining.

In addition, in manufacturing the sinter, by the MIM method, it is possible to obtain the sinter for manufacturing the variable vane having the higher dimensional precision than that in the prior art by adopting the above-described particle diameter of the metallic powder, tap density, binder amount, and binder components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

[FIG. 1]
FIG. 1A shows a variable vane having a flat top in a blade unit; and FIG. 1B shows a variable vane having a shaft on the top of the blade unit. In each of FIGS. 1A and 1B, (a) is a front view; (b) is a right side view; (c) is a bottom view; and (d) is a perspective view.

[FIG. 2]
FIG. 2 is a flowchart illustrating one embodiment of a variable vane manufacturing method according to the present invention.

[FIG. 3]
FIG. 3A shows the variable vane having the flat top of the blade unit; and FIG. 3B shows the variable vane having the shaft also on the top of the blade unit.

[FIG. 4]
FIGS. 4A to 4C are diagrams illustrating the variable vane having the flat top of the blade unit to be pressed in three processes.

[FIG. 5]
FIGS. 5A to 5C are diagrams illustrating the variable vane having the shaft also on the top of the blade unit to be pressed in three processes.
[FIG. 6]
FIG. 6 illustrates a molded body deformed after debinding in Comparative Example 2.

BEST MODES FOR CARRYING OUT THE INVENTION

[0020] As shown in FIGS. 1A and 1B, a variable vane for use in a turbocharger includes a blade unit (i.e., a nozzle vane unit) for adjusting the flow rate of exhaust gas and a shaft unit (i.e., a vane shaft unit) for pivotally supporting the blade unit, wherein the shaft unit is continuously connected at least onto one side (downward) from a rotational center position near the center of the blade unit. The shaft unit is columnar: in contrast, the blade unit is a flat wedge which is reduced in thickness toward the tip. In most case, the blade unit is finely and asymmetrically curved so as to readily adjust the flow rate of the exhaust gas, thereby enhancing incorporating stability and operational stability.
In the shaft unit, it is preferable that an end on a side opposite to an end continuously connected to the blade unit should be formed into a flat shape as a molded surface is, and further, the boundary between the end and a peripheral wall surface of the shaft unit should be curved. In this manner, there is no portion which is unnecessarily machined from the mechanical viewpoint, and further, strength can be enhanced. Moreover, the end of the shaft unit is curved, thereby enhancing incorporating stability and turning stability.
[0021] The product shapes are classified into two types: namely, a product having a flat top of a blade (see FIG. 1A) and a product having a rotary shaft also on the top (see FIG. 1B). FIG. 2 (i.e., a process flowchart) illustrates a product manufacturing method.
[0022] In manufacturing the variable vane, it is necessary to first manufacture a sinter having a shape similar to a desired final product. A molding material is obtained by adding the required amount of an organic binder to metallic powder as a raw material, to be then molded in a die in previous consideration of a shrinkage ratio of a sintered product, thus achieving a molded body.
[0023] Metal used for the variable vane has corrosion resistance and heat resistance. As metallic materials suitable for manufacturing the sinter is mainly used SUS310 or SCH21 (HK30) containing 19.0 to 22.0 wt% of Ni and 23.0 to 27.0 wt% of Cr. In addition, Ni-based alloys such as Inconel may be used.
As the metallic powder made of the above-described metallic material is normally used alloy powder produced by a water or gas atomizing method. Besides the alloy powder produced by the atomizing method, element powder which is adjusted to become an alloy component in sintering may be added according to a composition. In general, the water atomized powder can be produced in more quantity than the gas atomized powder, and therefore, a production cost is reduced. However, the powdery shape is liable to be varied, and therefore, tap density tends to be reduced, and further, oxygen amount contained in the powder becomes larger. In contrast, although the gas atomized powder is produced at a high cost, globular powder can be readily obtained, thereby enhancing the tap density. As a consequence, in consideration of the cost and the tap density, the water atomized powder and the gas atomized powder may be used in mixture.
[0024] The metallic powder (a) according to the present invention should preferably have an average particle diameter of 1 μm to 20 μm. In the case where the average particle diameter is less than 1 μm, an increase in surface area of the powder increases binder addition amount, thereby enlarging deformation in debinding. Here, if the binder amount becomes large, the shrinkage ratio in sintering also becomes great, thereby increasing dimensional variations after sintering. Therefore, it is difficult to obtain a product having a high dimensional precision in pressing in a post process. In contrast, in the case where the average particle diameter exceeds 20 μm, it is difficult to stably obtain a sintering density (i.e., a relative density) of 95% or more. Therefore, the strength is markedly decreased, thereby making the use as a product impossible. A more preferred average particle diameter ranges from 5 μm to 12 μm, and desirably, from 8 μm to 10μm. According to the present invention, the average particle diameter signifies an average diameter of weight accumulation of 50% measured by using a particle size distribution measuring device utilizing laser diffraction or scattering. As such a particle size distribution measuring device may be used an SALD-2000 type measuring device manufactured by Shimadzu Corporation.
[0025] Moreover, the metallic powder (a) according to the present invention should preferably have a tap density of 3.5 g/m^3 or more. In the case where the tap density of the powder is less than 3.5 g/m^3, an increase in surface area of the powder requires an increase in binder amount to be added. This causes dimensional variations during debinding and sintering. The more preferred tap density is 4.0 g/m^3 or more, and more preferably, 4.2 g/m^3 or more. Here, although the upper limit is not particularly defined, a satisfactory effect can be produced when the tap density is 5.0 g/m^3 or less. The tap density may be measured by a measuring method disclosed in JPMA P 08 of *Tap Density Test Method for Metallic Powder* published by Japan Powder Metallurgy Association.
[0026] As the organic binder (b) is used an organic binder containing 5 vol% to 40 vol% of polyacetal (b1) and 5 vol%

to 40 vol% of polypropylene (b2). Since the organic binder contains polyacetal and polypropylene, deformation during debinding can be suppressed in comparison with a conventional binder containing polyethylene, ethylene vinyl acetate, or an acrylic resin.

Polyacetal is essential in enhancing the strength of the molded body, preventing deformation of the molded body against the sintering at 600˚C or lower, and preventing carbide from remaining after the sintering. Polypropylene imparts tenacity to the molded body so as to inhibit any sintering crack or separation of an added compound having a low-melting point. Polypropylene also is equipped with the feature of preventing carbide from remaining after the sintering.

When the addition amount of each of polyacetal and polypropylene is less than 5 vol% with respect to the total amount (b) of the organic binder, deformation at the time of debinding becomes large, and therefore, the defined dimensional precision after the sintering cannot be obtained. In contrast, when the addition amount of each of polyacetal and polypropylene exceeds 40 vol% with respect to the total amount (b) of the organic binder, the viscosity at the time of molding becomes high, and therefore, the die cannot be completely filled with the molding material.

The much preferred contents of polyacetal range from 10 vol% to 30 vol%, and further, much preferred contents of polypropylene range from 10 vol% to 30 vol%.

[0027] Examples of usable organic materials other than polyacetal and polypropylene are as follows:

In order to impart fluidity and enhance debinding performance, there may be used fatty acid ester, fatty acid amide, phthalate ester, paraffin wax, microcrystalline wax, polyethylene wax, polypropylene wax, carnauba wax, montan-based wax, urethanized wax, maleic anhydride denatured wax, polyglycol-based compounds, and the like. As particularly preferred materials are listed paraffin wax, fatty acid ester, and polypropylene wax.

[0028] Moreover, in order to impart fluidity during the molding and flexibility to the molded body, there may be used polyethylene, amorphous polyolefin, ethylene vinyl acetate copolymers, acrylic resins, polyvinylbutyral resins, glycidyl methacrylate resins, and the like. As particularly preferred materials are listed polyethylene and amorphous polyolefin.

[0029] In order to enhance the fluidity and the debinding performance and impart the fluidity and the flexibility, it is preferable that the organic binder (b) should range from 30 vol% to 60 vol% with respect to the total amount (a + b) of the metallic powder (a) and the organic binder (b), more preferably, from 35 vol% to 50 vol%.

The organic binder and the metallic powder in the above-described ratio are heated and kneaded for about 2 hours at about 160˚C to 180˚C, so that the metallic powder is completely dispersed and mixed in the organic binder. Thereafter, the resultant product are taken out and formed into a pellet having a diameter of about 5 mm by an extruder or a grinder, thereby obtaining a molding material.

[0030] In consideration of the dimensional variations of the sinter caused by pressing, it is necessary to manufacture a blade unit in such a manner as to become +0.3% to +0.9% of a dimension desired for a final product in a height direction and -0.6% to -0.0% of a dimension desired for the final product in a thickness direction whereas to manufacture a shaft unit in such a manner as to have a diameter of +0.3% to +0.9% of a dimension desired for a final product and a length (i.e., length of the shaft unit under the blade unit) of -0.6% to -0.0% of a dimension desired for a final product.

In molding, the shape of the die need be determined in consideration of the dimensions after the sintering. These dimensions are obtained after the sintering or hot isotropic pressurizing, and further, they depend upon sintering density, so that the die need be designed in full consideration of dimensional variations thereafter. As a consequence, the dimension of the die need be designed in consideration of the dimensional precision, and further, the shrinkage ratio from the molding to the sintering need be calculated in advance.

[0031] In the case where the conventional organic binder system is used, the deformation occurs during debinding, and therefore, it is very difficult to obtain a product within the dimensional range of the above-described sinter. However, the sinter having a higher dimensional precision than that in the prior art can be manufactured by the MIM method by achieving the above-described particle diameter of the metallic powder, tap density, binder amount, and binder components.

[0032] Here, the thickness of the blade unit in the variable vane is gradually reduced in thickness from the rear end of the blade unit (left in FIG. 1) toward the fore end (right in FIG. 1), as shown in FIG. 1, and therefore, it depends upon a portion to be measured. According to the present invention, the thickness of the blade unit within the range of -0.6% to -0.0% with respect to the target dimension of the final product signifies that a difference when the final product and the sinter (having a shape approximate to that of the final product) are measured at corresponding portions falls within the above-described range.

As for the height of the blade unit, the diameter of the shaft unit, and the length from the lower end of the blade unit to the lower end of the shaft unit, if they depend upon a portion to be measured, they signify that the difference when the final product and the sinter are measured at the corresponding portions, like the thickness of the blade unit, falls within the above-described range.

[0033] The die is fixed to an injection molder, followed by molding. The number of molded bodies obtained may be one to eight per die in consideration of the size of the product and the mass-produced number- The capacity of the injection molder is appropriately adjusted according to the number taken by the die or the size of the product. In general, molding is performed by using a molder having a caulking force from about 20 ton to about 100 ton. An injection speed and pressure are adjusted such that no deficiency such as bubbles or cracks occurs in the molded body. Furthermore, the die need be provided with a gas relief for effectively relieving air staying inside of the die and gas generated from the molding material. If there is no effective gas relief, the air or gas generated from the molding material is taken into the molded body, and thus, bubbles are generated in the molded body.

[0034] The resultant molded body is put into a debinding furnace, and then, the added organic binder is removed. The organic binder is removed in the debinding furnace in any one of a reduced pressure inactive gas atmosphere, an atmospheric inactive gas atmosphere, and an atmospheric hydrogen gas atmosphere. In the case of a sintering device equipped with a debinding function, debinding and sintering can be performed consistently. As the debinding furnace, a batch type or a continuous type (i.e., a belt type, a pusher type, or a walking beam type) may be used. Since the deformation may become large in debinding, debinding is effectively carried out by using a jig having a shape in conformity with the shape of the molded body so as to suppress the deformation to the minimum.

[0035] The debinding is carried out at a highest temperature of 800˚C or less in any one of the reduced pressure inactive gas atmosphere, the atmospheric inactive gas atmosphere, and the atmospheric hydrogen gas atmosphere.
If the debinding is carried out in the air, the powder is oxidized at 300˚C or higher, and therefore, the amount of oxygen after sintering becomes large, thereby largely influencing on the strength of a sinter. In view of this, the debinding is carried out in the reduced pressure inactive gas atmosphere, the atmospheric inactive gas atmosphere, or the atmospheric hydrogen gas atmosphere. Nitrogen or argon is used as the inactive gas. Here, nitrogen gas is desired from the viewpoint of a cost. A temperature increasing rate is desirably 50˚C/hr from room temperature to 400˚C or lower in consideration of the deformation at the time of the debinding. The use of the jig in consideration of the deformation of the molded body at the time of the debinding can suppress the deformation of the molded body at the time of the debinding. Temperature at the time of the debinding is 800˚C or lower. About 30% of the organic binder is liable to remain at about 300˚C whereas the organic binder is liable to be completely removed at 600˚C or higher, whereby the molded body is likely to collapse when it proceeds to the sintering. More preferably, the debinding temperature ranges from 400˚C to 500˚C to the maximum. In addition, the use of a sintering furnace equipped with a debinding function is effective in preventing any collapse of the molded body, and further, in transiting to the sintering without any decrease in temperature also after the completion of the debinding. Furthermore, the debinding and sintering can be continuously carried out without any intermission by connecting a continuous type (i.e., a belt type, a pusher type, or a walking beam type) debinding furnace and a continuous type (i.e., a belt type, a pusher type, or a walking beam type) sintering furnace to each other.

[0036] The atmosphere in the sintering process is selected from a reduced pressure inactive gas atmosphere, an atmospheric inactive gas atmosphere, a pressurizing inactive gas atmosphere, and an atmospheric hydrogen gas atmosphere. Since a stainless material is mostly used in sintering, argon gas should be preferably used as inactive gas in consideration of the nitrogenation of a material.
In addition, the sintering is carried out at a temperature of 1000˚C or higher to 1500˚C or lower. At a temperature of lower than 1000˚C, the sintering is insufficient: in contrast, in excess of 1500˚C, the molded body is melted during the sintering. The temperatures from 1200˚C to 1400˚C should be desirable so as to achieve a sintering density of 95% or more, and 1250˚C to 1380˚C should be more desirable. The molded body should be desirably held for about 2 to 4 hours at a highest temperature in consideration of the enhancement of the sintering density during the sintering and the dimensional variations during the sintering. Additionally, like in the debinding process, deformation is liable to be generated at a high temperature also in the sintering process, and therefore, the use of a jig for preventing any deformation of a sinter is effective.

[0037] In consideration of production amount in the debinding and sintering processes, flexible manufacture requires batch type debinding and sintering furnaces- In the case of the increased number of products, the production amount can be remarkably increased by continuously debinding and sintering by the use of a pusher type continuous furnace, a walking beam type continuous furnace, or a belt type continuous furnace.

[0038] Mechanical strength and hardness can be held at high temperature by setting the density of the sinter to a relative density of 95% or more. If the relative density does not reach 95%, the mechanical strength, in particular, elongation and the hardness are reduced at the high temperature, thereby making the continuous use at the high temperature difficult.
The relative density of the sinter may be measured by the Archimedean method.

[0039] It is effective that the resultant sinter is further processed by the hot isotropic pressurizing (HIP) method in order to further increase the sintering density so as to enhance the mechanical strength and enhance the reliability of the mechanical strength in a high-temperature region. The HIP process is performed at a high pressure from about 10 MPa to 180 MPa at a temperature lower by 10˚C to 100˚C than the sintering temperature, thereby stably obtaining a sinter having a relative density of 98% or more without any pinholes inside thereof. Moreover, during the sintering, a sinter having a relative density of 98% or more can be obtained without using the HIP method in post-processes by using a sintering HIP device capable of pressurizing at about 6 MPa at highest.

[0040] The sinter after the sintering or the HIP process is formed in a desired dimension of a final product by pressing

illustrated in FIGS. 4 and 5.
The dimensions of the blade unit in the height and width (i.e., thickness) directions are set to those of the desired product at the same time in a first pressing process. Next, the coaxiality of the blade unit and the shaft unit is set to the desired dimension of the product in a second pressing process. Subsequently, the roundness of the shaft is set to the desired dimension of the product in a third pressing process. As a consequence, the shaft unit and the blade unit can be shaped into the desired dimensions without machining.
Hereinafter, each of the pressing processes will be described in details.

First Pressing Process (Adjusting Dimension of Blade Unit)

[0041] In the first pressing process, a die includes a lower die for holding a sinter and an upper die for defining the blade unit in both the height and width directions at the same time. The blade unit is compressed downward by pressing the upper die against the lower die. When the upper surface of the blade unit is compressed, the side portion is expanded and deformed in conformity with the shape of the die, thus achieving the desired height and side surface of the blade unit, the shape of the blade, and the squareness of the shaft with respect to the blade.

Second Pressing Process (Adjusting Coaxiality between Blade Unit and Shaft Unit)

[0042] In the second pressing process, a die includes an upper die and a lower die formed into a shape in which the blade unit and the shaft unit in the variable vane are bisected (the dies are bisected on a surface bisecting the thickness of the blade unit). The sinter is fixed to the lower die in a lateral direction whereas the upper die is pressed downward, so that the blade unit and the shaft unit are compressed at the same time, thereby achieving the verticality of the shaft with respect to the blade unit and the coaxiality of the shaft with respect to the blade unit.

Third Pressing Process (Adjusting Roundness of Shaft Unit)

[0043] In the third pressing process, a die includes an upper die and a lower die formed into a shape (i.e., semi-columnar shape) in which the shaft unit under the blade unit is bisected in the axial direction. The shaft unit of the sinter obtained in the second pressing process is turned at 90˚, followed by vertical pressing, thereby achieving the roundness of the shaft unit.
[0044] The above-described sinter is subjected to post-processing in the three-step pressing, so that the desired variable vane can be obtained without machining. The material of the die for use in pressing is selected from die steel, high-speed steel, and carbide steel in consideration of the lifetime. In order to save energy, the pressing capacity per hour can be remarkably enhanced by using a part feeder and a progressive device in comparison with the conventional machining. Specifically, the number of products machined per hour can be increased up to about 300 to 600.
[0045] In order to further save energy required for pressing, a multiple forming machine capable of pressing and bending at 360˚ is used in pressing. As a result, energy can be saved during pressing. Conventionally, only about 10 to 50 products per hour can be machined by cutting the shaft and blade units by one machine. However, the capacity can be remarkably enhanced up to 500 to 1000 products per hour.
[0046] Additionally, the pressed product is subjected to barrel polishing or electrolytic polishing, as required, thereby enhancing surface roughness, and further, removing a burr.
[0047] According to the present invention, the sinter which has been obtained by the MIM process and whose dimensional precision has been controlled in advance is used as the material. Consequently, it is possible to fabricate the variable vane having the desired shape excellent in dimensional precision without cutting or polishing by machining in post-processing. According to the present invention, the adoption of the MIM method, in particular, can suppress the material fabrication loss down to 5% or less even in comparison with a lost wax or the punching of a plate material in the prior art, and thus, cost can be effectively reduced- In addition, the fabrication efficiency becomes 5 to 10 times in comparison with the fabrication by the conventional machining by automating the pressing. Moreover, the adoption of the MIM method can implement the mass production of the thin variable vane having the complicated shape which could be hardly obtained with ease in the prior art.

EXAMPLE 1

[0048] The sinter according to the present invention was manufactured- The molding material and the conditions of heating/kneading, injection molding, debinding, sintering, and the like were as described below. A hundred molded bodies were molded, followed by debinding and sintering, and then, dimensional variations were measured.

- Metallic powder: SUS310 having an average particle diameter of 9.2 μm and a tap density of 4.2 g/m^3

- Composition of organic binder: 15 vol% of polyacetal, 25 vol% of polypropylene, 10 vol% of amorphous polyolefin, 35 vol% of paraffin wax, 10 vol% of acrylic resin, and 5 vol% of fatty acid ester
- 60 vol% of metallic powder and 40 vol% of organic binder
- Heating/kneading: at 180˚C for 2 hours
- Injection molding condition: at 180˚C with a die temperature of 40˚C
- Debinding condition: held at a highest temperature of 500˚C for 2 hours (in nitrogen), 24 hours in total
- Sintering condition: held at a highest temperature of 1350˚C for 2 hours (in argon and in vacuum)

[0049] One die for injection molding was taken out. The variable vane had the shape shown in FIG. 3A. The dimensions of the desired final product were described below. Here, A1 designates the height of the blade unit; B1, the thickness of the blade unit; C1, the diameter of the shaft unit; and D1, the length of the shaft unit positioned under the blade unit (i.e., the length from the lower end of the blade unit to the lower end of the shaft unit).

DESIRED DIMENSIONS OF FINAL PRODUCT

[0050]

A1: 6.0 mm (target dimension) ±0.01 mm (5.99 mm to 6.01 mm)
B1: 2-5 mm (target dimension) ±0.03 mm (2.47 mm to 2.53 mm)
C1: 4.0 mm (target dimension) ±0.01 mm (3.99 mm to 4.01 mm)
D1: 10.0 mm (target dimension) ±0.05 mm (9.95 mm to 10.05 mm)
Coaxiality between Shaft and Blade Unit: within 0.03 mm
Verticality: within 0.03 mm
Parallelism of Blade Unit: within 0.03 mm

[0051] A molding machine having a caulking pressure of 30 ton was used. The dimensions of the manufactured sinter were described below. The dimensions were measured by using a tool microscope.

DIMENSIONS OF MANUFACTURED SINTER

[0052]

A1: 6.024 mm to 6.044 mm (target dimension +0.4% to +0.73%)
B1: 2.485 mm to 2.494 mm (target dimension -0.60% to - 0.24%)
C1: 4.018 mm to 4.030 mm (target dimension +0.45% to +0.75%)
D1: 9.955 mm to 9.980 mm (target dimension -0.45% to - 0.2%)
Coaxiality between Shaft and Blade Unit: 0.035 mm
Verticality: 0.042 mm
Parallelism of Blade Unit: 0.038 mm
Sintering Density: 96.0%

[0053] The pressing was performed according to the process illustrated in FIG. 4. The dimensions after the pressing were described below.

DIMENSIONS OF MANUFACTURED FINAL PRODUCT

[0054]

A1: 5.994 mm to 6.003 mm
B1: 2.489 mm to 2-515 mm
C1: 3.996 mm to 4.004 mm
D1: 9.984 mm to 10.029 mm
Coaxiality between Shaft and Blade Unit: 0.017 mm
Verticality: 0.009 mm
Parallelism of Blade Unit: 0.015 mm

[0055] After sintering, the desired dimensions of the final product could not be obtained. However, the product having the dimensions which fell within dimensional tolerances of the final product in the pressing could be obtained.

EXAMPLE 2

[0056] The sinter according to the present invention was manufactured. The molding material and the conditions of heating/kneading, injection molding, debinding, sintering, and the like were as described below. A hundred molded bodies were molded, followed by debinding and sintering, and then, dimensional variations were measured.

- Metallic powder: HK30 having an average particle diameter of 8.7 μm and a tap density of 4.3 g/m^3
- Composition of organic binder: 20 vol% of polyacetal, 20 vol% of polypropylene, 10 vol% of amorphous polyolefin, 35 vol% of paraffin wax, 10 vol% of acrylic resin, and 5 vol% of fatty acid ester
- 60 vol% of metallic powder and 40 vol% of organic binder
- Heating/kneading: at 180˚C for 2 hours
- Injection molding condition: at 180˚C with a die temperature of 40˚C
- Debinding condition: held at a highest temperature of 500˚C for 2 hours (in nitrogen), 24 hours in total
- Sintering condition: held at a highest temperature of 1350˚C for 2 hours (in argon and in vacuum)
- HIP process: held at a processing temperature of 1200˚C for 2 hours (in argon and at 100 MPa)

[0057] One die for injection molding was taken out. The variable vane had the shape shown in FIG. 3B. The desired dimensions of the final product were described below. Here, A2 designates the height of the blade unit; B2, the thickness of the blade unit; C2, the diameter of the shaft unit; and D2, the length of the shaft unit positioned under the blade unit.

DESIRED DIMENSIONS OF FINAL PRODUCT

[0058]

A2: 6.0 mm (target dimension) ±0.01 mm (5.99 mm to 6.01 mm)
B2: 2.5 mm (target dimension) ±0.03 mm (2.47 mm to 2.53 mm)
C2: 4.0 mm (target dimension) ±0.01 mm (3.99 mm to 4.01 mm)
D2: 10.0 mm (target dimension) ±0.05 mm (9.95 mm to 10.05 mm)
Coaxiality between Shaft and Blade Unit: within 0.05 mm
Verticality: within 0.03 mm
Parallelism of Blade Unit: within 0.03 mm

[0059] A molding machine having a caulking pressure of 30 ton was used. The dimensions of the manufactured sinter were described below. The dimensions were measured by using a tool microscope. Here, C2a designates the diameter of the shaft unit positioned under the blade unit: in contrast, C2b designates the diameter of the shaft unit positioned above the blade unit.

DIMENSIONS OF MANUFACTURED SINTER

[0060]

A2: 6.024 mm to 6.049 mm (target dimension +0.4% to +0.82%)
B2: 2.487 mm to 2.494 mm (target dimension -0.52% to - 0.24%)
C2a: 4.016 mm to 4.028 mm (target dimension +0.4% to +0.7%)
C2b: 4.015 mm to 4.031 mm (target dimension +0.38% to +0.78%)
D2: 9.961 mm to 9.992 mm (target dimension -0.39% to - 0.08%)
Coaxiality between Shaft and Blade Unit: 0.062 mm
Verticality: 0.044 mm
Parallelism of Blade Unit: 0.035 mm
Sintering Density: 99.2%

[0061] The pressing was performed according to the process illustrated in FIG. 5. The dimensions after the pressing were described below.

DIMENSIONS OF MANUFACTURED FINAL PRODUCT

[0062]

A2: 5.993 mm to 6.005 mm
B2: 2.479 mm to 2.505 mm
C2a: 3.995 mm to 4.003 mm
C2b: 3.996 mm to 4.002 mm
D2: 9.982 mm to 10.023 mm
Coaxiality between Shaft and Blade Unit: 0.031 mm
Verticality: 0.014 mm
Parallelism of Blade Unit: 0.016 mm

[0063] After sintering, the desired dimensions of the final product could not be obtained. However, the product having the dimensions which fell within dimensional tolerances of the final product in the pressing could be obtained.

[Comparative Example 1]

[0064] A sinter below was manufactured under the same conditions as those in EXAMPLE 1.

DIMENSIONS OF MANUFACTURED SINTER

[0065]

A1: 5.985 mm to 6.005 mm (target dimension -0.25% to +0.08%)
B1: 2.490 mm to 2.505 mm (target dimension -0.4% to +0.2%)
C1: 3.985 mm to 4.006 mm (target dimension -0.38% to +0.15%)
D1: 9.985 mm to 10.005 mm (target dimension -0.15% to +0.05%)
Coaxiality between Shaft and Blade Unit: 0.040 mm
Verticality: 0.044 mm
Parallelism of Blade Unit: 0.039 mm
Sintering Density: 96.0%

[0066] The sinter was subjected to the three-step pressing under the same conditions as those in EXAMPLE 1. The dimensions after the pressing were as follows.

DIMENSIONS OF MANUFACTURED FINAL PRODUCT

[0067]

A1: 5.985 mm to 6.003 mm
B1: 2.490 mm to 2.515 mm
C1: 3.986 mm to 4.003 mm
D1: 9.986 mm to 10.009 mm
Coaxiality between Shaft and Blade Unit: 0.032 mm
Verticality: 0.036 mm
Parallelism of Blade Unit: 0.030 mm

[0068] The product whose sinter had the dimensions approximate to those of the final product was manufactured. However, the product could not have the dimensions A1 and C1 which fell within the dimensional tolerance of the final product. In addition, the coaxiality and verticality could not fall within the tolerance.
This was because the dimensions A1 and C1 of the sinter before the pressing were largely apart from the desired dimensions of the final product.

EXAMPLE 3

[0069] In addition, in order to examine the difference between the dimensions A to D of the sinter and the target dimensions of the final product adversely influencing on the final product, various sinters were manufactured under the same conditions as those in EXAMPLE 1, and then, the relationship between the final product after the pressing and the sinter before the pressing was examined. The results are shown below in Table 1.
[0070]

[Table 1]

<table>
<tr><th colspan="4">Dimensional precision of sinter with respect to target dimension (%)*1</th><th rowspan="2">Relative density</th><th rowspan="2" colspan="2">Evaluation</th></tr>
<tr><th>Height of blade unit (A)</th><th>Thickn ess of blade unit (B)</th><th>Diamet er of shaft unit (C)</th><th>Length of shaft unit (D*2)</th></tr>
<tr><td>+0.2</td><td rowspan="6">-0.3</td><td rowspan="12">+0.6</td><td rowspan="18">-0.3</td><td rowspan="20">97%</td><td>Δ</td><td>A was less than defined dimension.</td></tr>
<tr><td>+0.3</td><td>○</td><td></td></tr>
<tr><td>+0.5</td><td>⊙</td><td></td></tr>
<tr><td>+0.7</td><td>⊙</td><td></td></tr>
<tr><td>+0.9</td><td>○</td><td></td></tr>
<tr><td>+1.0</td><td>×</td><td>A was more than defined dimensions.</td></tr>
<tr><td rowspan="14">+0.6</td><td>-0.7</td><td>×</td><td>B was less than defined dimension.</td></tr>
<tr><td>-0.6</td><td>○</td><td></td></tr>
<tr><td>-0.4</td><td></td><td></td></tr>
<tr><td>-0.2</td><td>⊙</td><td></td></tr>
<tr><td>-0.0</td><td>○</td><td></td></tr>
<tr><td>+0.1</td><td>×</td><td>B was more than defined dimension.</td></tr>
<tr><td rowspan="8">-0.3</td><td>+0.2</td><td>×</td><td>C was less than defined dimension.</td></tr>
<tr><td>+0.3</td><td>○</td><td></td></tr>
<tr><td>+0.5</td><td>⊙</td><td></td></tr>
<tr><td>+0.7</td><td>⊙</td><td></td></tr>
<tr><td>+0.9</td><td>○</td><td></td></tr>
<tr><td>+1.0</td><td>×</td><td>C was more than defined dimension.</td></tr>
<tr><td>+0.6</td><td>-0.7</td><td>×</td><td>D was less than defined dimension.</td></tr>
<tr><td></td><td>-0.6</td><td>○</td><td></td></tr>
</table>

(continued)

Dimensional precision of sinter with respect to target dimension (%)*1				Relative density	Evaluation	
Height of blade unit (A)	Thickn ess of blade unit (B)	Diamet er of shaft unit (C)	Length of shaft unit (D*2)			
			-0.4		⊙	
			-0.2		⊙	
			-0.0		○	
			+0.1		Δ	D wasmore than defined dimension.
			-0.3	94%	×	B and D were out of defined dimensions.
				95%	○	
				97%	⊙	
				99%	⊙	
				99.5%	○	

*1 (Dimension of sinter - target dimension) x 100/target dimension
*2 D = length from lower end of blade unit to lower end of shaft unit

[0071] From the results of EXAMPLE 3, the sinter before the pressing had the dimensions below with respect to the desired dimensions of the final product (i.e., the target dimensions): the height of the blade unit ranged from +0.3% to +0.9%; the thickness of the blade unit ranged from -0.6% to -0.0%; the diameter of the shaft unit ranged from +0.3% to +0.9%; the length from the lower end of the blade unit to the lower end of the shaft unit ranged from -0.6% to -0.0%; and the sintering density was 95% or more of the relative density. In this case, it was found that the final product having the desired dimensional tolerance could be obtained only by pressing.

[Comparative Example 2]

[0072] A sinter was manufactured in the same manner as EXAMPLE 1 except that polyacetal out of the components of the organic binder in EXAMPLE 1 was replaced with an ethylene vinyl acetate resin.
However, after debinding, a blade unit in a molded body was inclined at 30° or more, as shown in FIG. 6. Due to the large deformation, the molded body could not be subjected to the following sintering and pressing.
[0073] In the case where an organic binder including polyethylene in place of polypropylene was used, a blade unit in a molded body was inclined at 10° or more after debinding, as shown in FIG. 6. Due to the large deformation, the molded body could not be subjected to the following sintering and pressing.
[0074] Besides, molded bodies were made of various injection molding materials, to be subjected to debinding and sintering. As a result, when metallic powder having an average particle diameter of 1 μm to 20 μm and a tap density of 3.5 g/m^3 or more was used, and further, an organic binder including 5 vol% to 40 vol% of polyacetal and 5 vol% to 40 vol% of polypropylene was used, wherein the organic binder ranged from 30 vol% to 60 vol% with respect to the total amount of the metallic powder and the organic binder, it was found that a sinter suitable for the use in the pressing according to the present invention could be obtained.

Explanation of Numerals in Figures

[0075]

1 variable vane
2 blade unit
3 shaft unit (positioned under blade unit)
3' shaft unit (positioned above blade unit)

Claims

1. A method for manufacturing a variable vane including a planar blade unit and a columnar shaft unit positioned under the blade unit, the method comprising the step of:

   pressing a sinter having a shape approximate to that of a desired final product;
   wherein the sinter is integrally constituted of the blade unit and the shaft unit, and has the height of the blade unit within +0.3% to +0.9%, the thickness of the blade unit within -0.6% to -0.0%, the diameter of the shaft unit within +0.3% to +0.9%, the length from the lower end of the blade unit to the lower end of the shaft unit within -0.6% to -0.0% with respect to the target dimensions of the final product, and a sintering density of 95% or more of a relative density, and
   wherein the pressing process includes three processes:

      in a first pressing process, the sinter is pressed with a lower die having a shaft unit insertion hole and an upper die having a shape except a lower end surface of the blade unit, so as to adjust the height and thickness of the blade unit;
      in a second pressing process, the blade unit and shaft unit of the sinter are pressed at the same time with an upper die and a lower die, each of which has a shape obtained by dividing the variable vane at a surface at which the thickness of the blade unit is bisected, so as to adjust the angle of the shaft unit with respect to the blade unit and the coaxiality of the shaft unit with respect to the blade unit; and
      in a third pressing process, the shaft unit of the sinter is pressed in a direction turned at 90˚ from that in the second pressing process with an upper die and a lower die, each of which has a semi-columnar shape corresponding to the shaft unit of the variable vane, so as to adjust the roundness of the shaft unit.

2. The method for manufacturing a variable vane according to claim 1, wherein the sinter is a sinter having a relative density of 98% or more.

3. The method for manufacturing a variable vane according to claim 1 or claim 2, wherein the first to third pressing processes are continuously performed by using a multiple forming machine capable of pressing and bending in directions of 360˚.

4. The method for manufacturing a variable vane according to any one of claims 1 to 3, further comprising a manufacturing process of the sinter which includes adding an organic binder (b) into metallic powder (a), followed by heating and mixing, obtaining an injection molding material by pulverizing or pelleting, preparing a molded body by injection-molding the molding material, and thermal debinding the resultant molded body,
   wherein the metallic powder (a) is powder having an average particle diameter of 1 μm to 20 μm and a tap density of 3.5 g/m^3 or more;
   the organic binder (b) contains 5 vol% to 40 vol% of polyacetal (b1) and 5 vol% to 40 vol% of polypropylene (b2); and in adding the organic binder (b) into the metallic powder (a), the organic binder (b) is added within a range of 30 vol% to 60 vol% with respect to the total amount (a+b) of the metallic powder and the organic binder.

5. The method for manufacturing a variable vane according to claim 4, wherein in manufacturing the sinter, the debinding is performed at a highest temperature of 800˚C or lower in any of a reduced pressure inactive gas atmosphere, an atmospheric pressure inactive gas atmosphere, and an atmospheric pressure hydrogen atmosphere; and
   the sintering is performed at a temperature from 1000˚C or higher and 1500˚C or lower in any of a reduced pressure inactive gas atmosphere, a pressurized inactive gas atmosphere, an atmospheric pressure inactive gas atmosphere, and an atmospheric pressure hydrogen atmosphere.

6. The method for manufacturing a variable vane according to claim 4 or claim 5, wherein in the sinter manufacturing process, a primary sinter having a relative density of 94% or more is manufactured, and then a sinter having a relative density of 98% or more is obtained by hot isotropic pressuring.

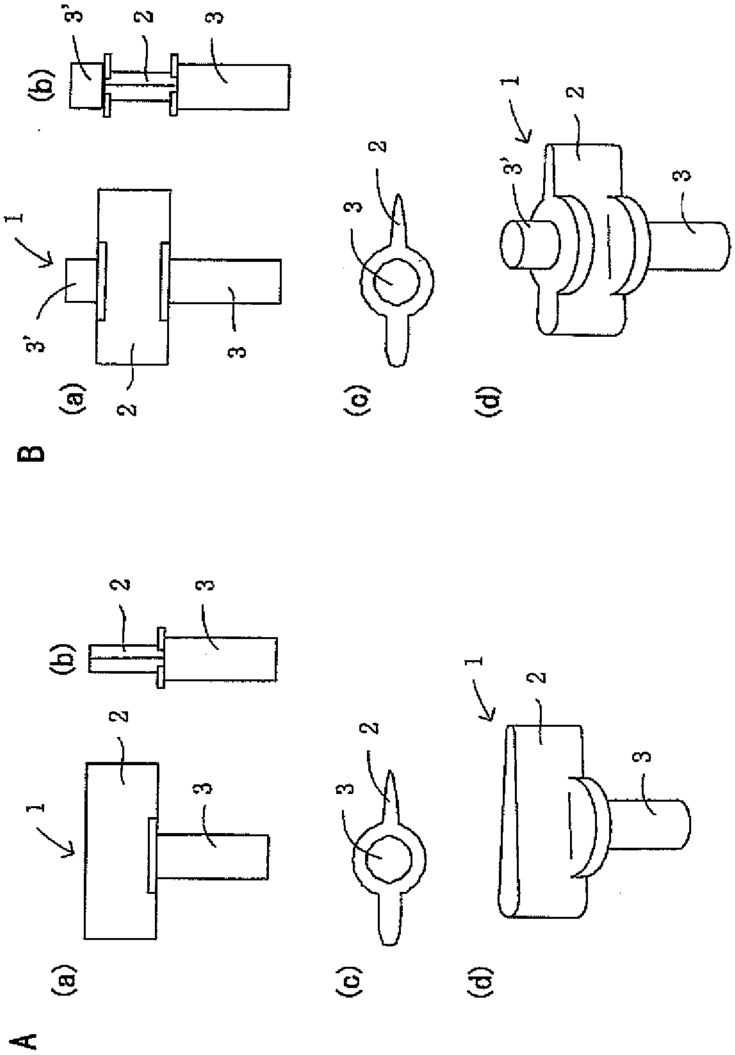
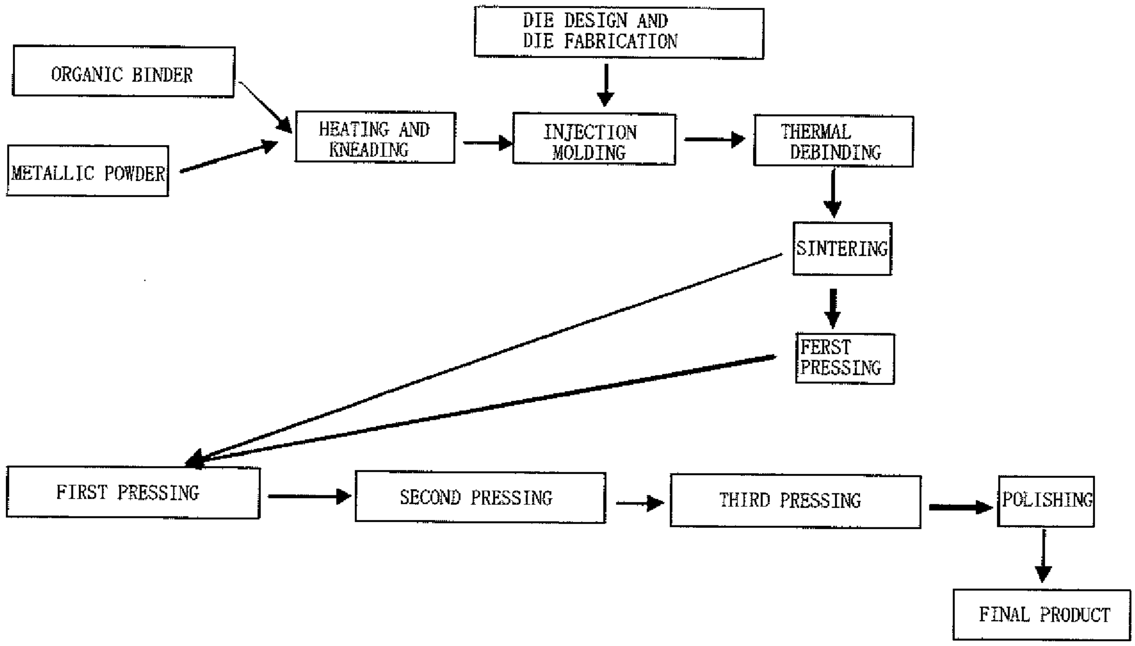


FIG.1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METALLIC POWDER
HEATING AND
KNEADING
INJECTION
MOLDING
THERMAL
DEBINDING
SINTERING
FERST
PRESSING
FIRST PRESSING
SECOND PRESSING
THIRD PRESSING
POLISHING
FINAL PRODUCT

FIG.2

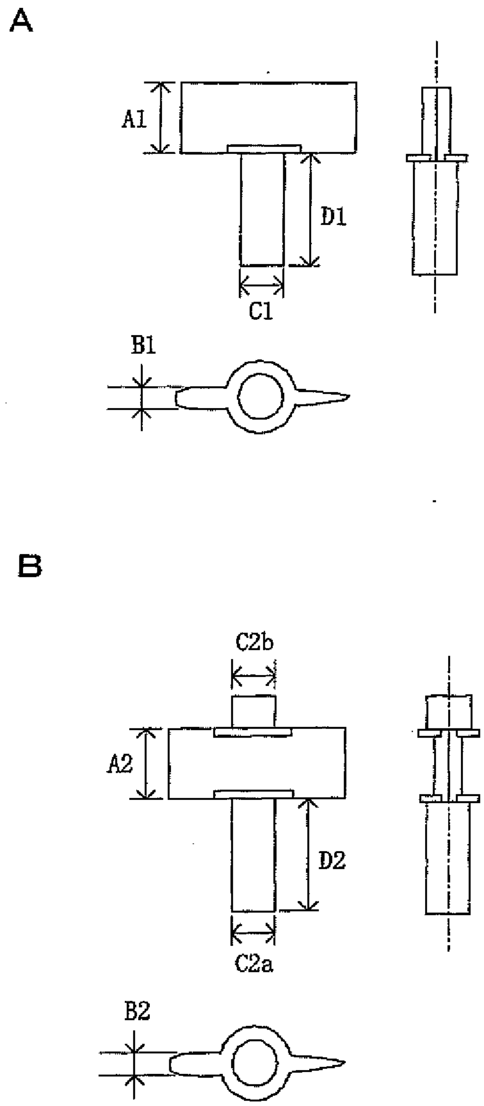
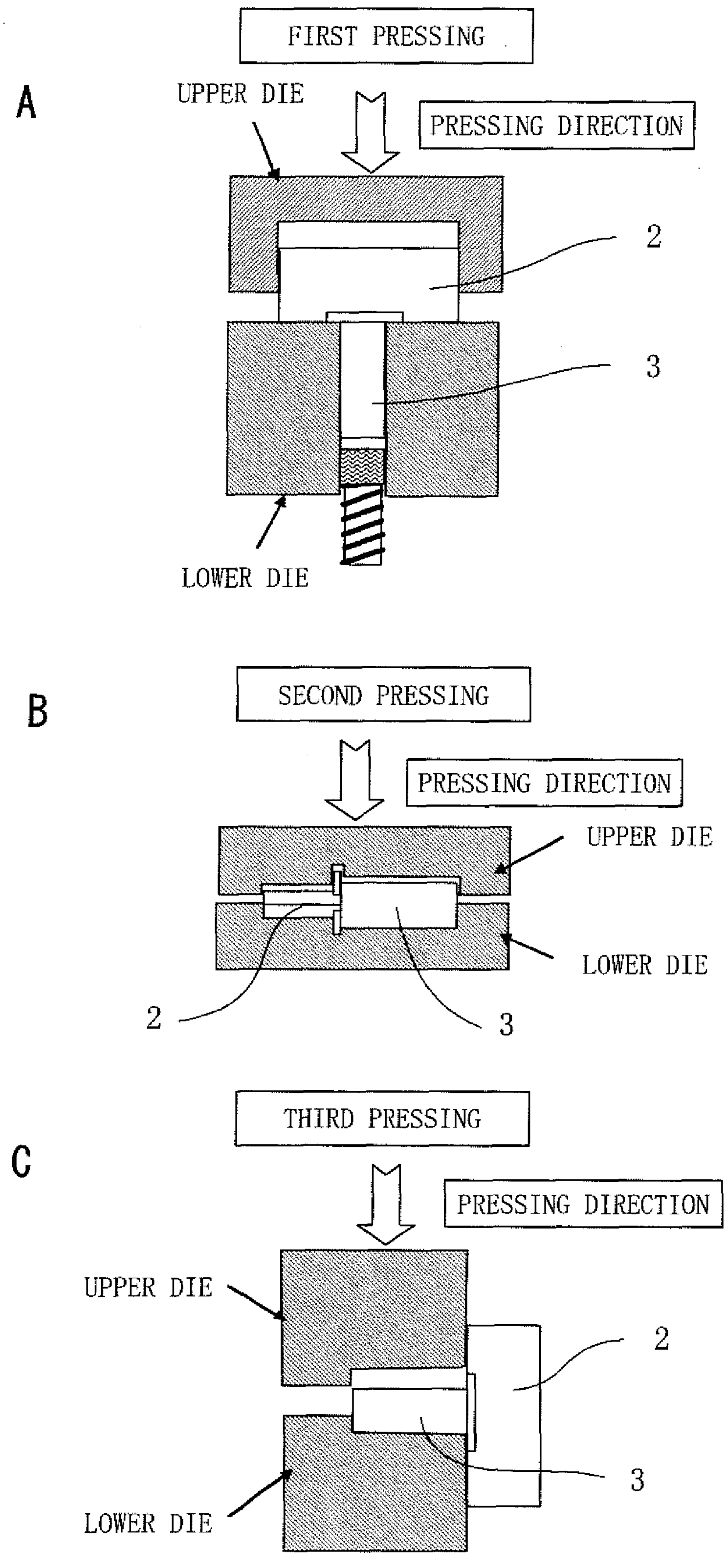


FIG.3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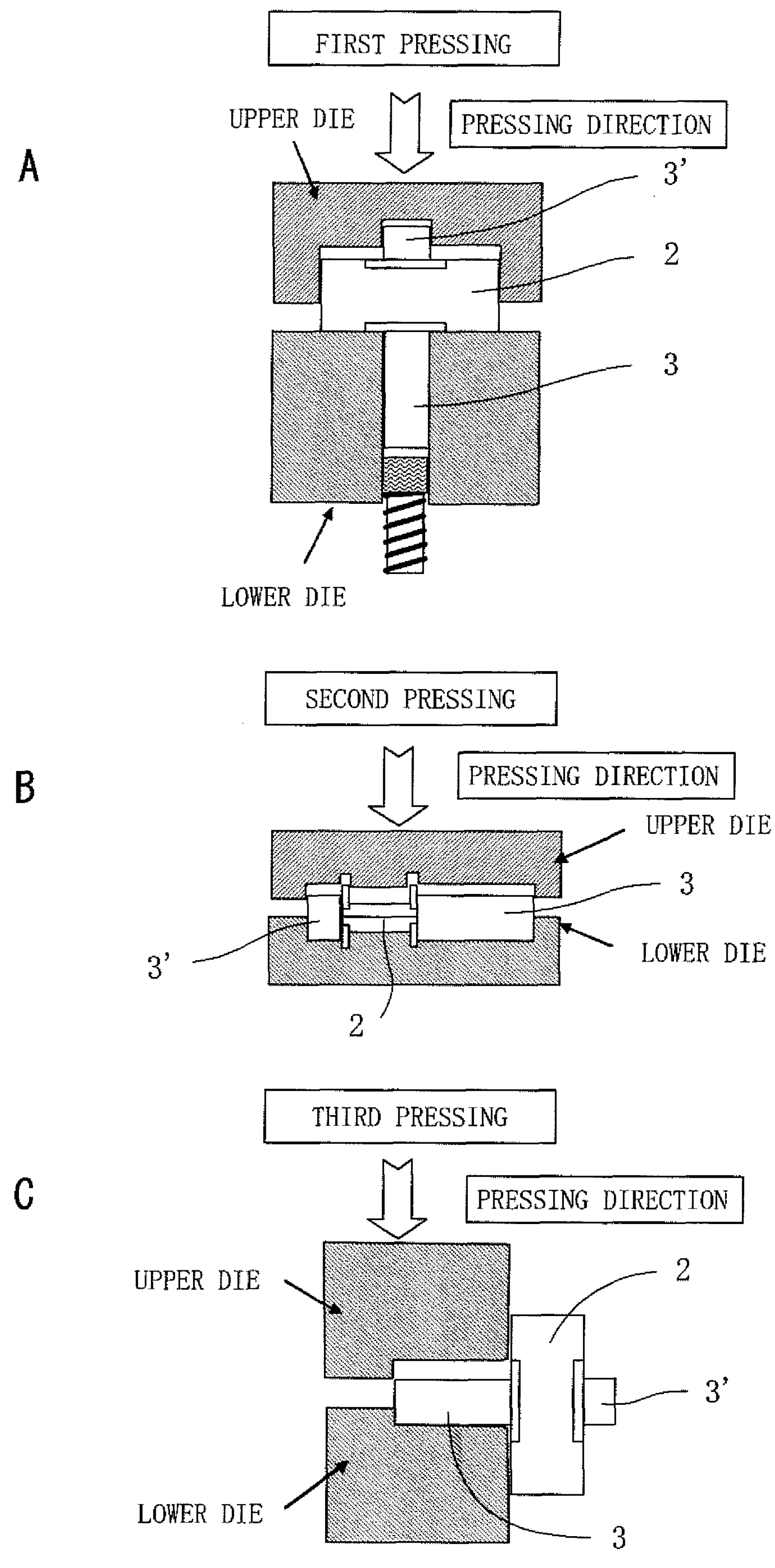
UPPER DIE
PRESSING DIRECTION
2
3
LOWER DIE
B
SECOND PRESSING
PRESSING DIRECTION
UPPER DIE
LOWER DIE
2
3
C
THIRD PRESSING
PRESSING DIRECTION
UPPER DIE
2
3
LOWER DIE

FIG. 4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UPPER DIE
PRESSING DIRECTION
A
3'
2
3
LOWER DIE
SECOND PRESSING
PRESSING DIRECTION
B
UPPER DIE
3
3'
LOWER DIE
2
THIRD PRESSING
C
PRESSING DIRECTION
UPPER DIE
2
3'
LOWER DIE
3

FIG.5

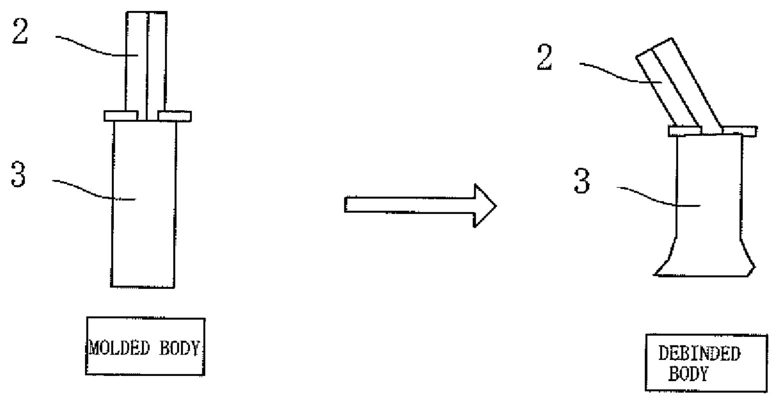

FIG.6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/067621

A. CLASSIFICATION OF SUBJECT MATTER
F02B37/24(2006.01)i, *B22F3/24*(2006.01)i, *B22F5/00*(2006.01)i, *F01D25/00*(2006.01)i, *F02B39/00*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02B37/24, B22F3/24, B22F5/00, F01D25/00, F02B39/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-049660 A (Soghi Kogyo Co., Ltd.), 21 February 2003 (21.02.2003), entire text; all drawings & US 2004/0237521 A1 & EP 1422400 A1 & WO 2003/014548 A1 & CN 1561433 A & HK 1073149 A	1-6
A	JP 2008-179860 A (Kabushiki Kaisha Tekunesu), 07 August 2008 (07.08.2008), entire text; all drawings (Family: none)	1-6
A	JP 62-280303 A (Osaka Fuji Corp.), 05 December 1987 (05.12.1987), entire text; all drawings (Family: none)	1-6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
15 December, 2009 (15.12.09)

Date of mailing of the international search report
28 December, 2009 (28.12.09)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

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Form PCT/ISA/210 (second sheet) (April 2007)

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Patent documents cited in the description

- JP 3833002 B **[0008]**
- JP 3944819 B **[0008]**
- JP 2008088849 A **[0008]**