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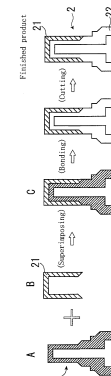
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## (54) **FUEL INJECTION NOZZLE FOR INTERNAL COMBUSTION ENGINE, NOZZLE BLANK AND MANUFACTURING METHOD THEREOF**

(57) Provided are a fuel injection nozzle for an internal combustion engine, a nozzle blank, and a manufacturing method for the nozzle blank, wherein the production processes are simple, the productivity is high, and the production can be performed at a low cost and with a high precision. A fuel injection nozzle for an internal combustion engine has a two layer structure of different materials, comprised of a nozzle body and a nozzle tip outer surface member which is arranged to cover a tip outer surface side of the nozzle body. The nozzle body is formed of a mold which has been molded into a predetermined shape by a metal powder injection molding method and which has been subjected to degreasing to obtain a degreased body forming the nozzle body. Likewise, separately, the nozzle tip outer surface member is formed of a mold which has been molded into a predetermined shape by a metal powder injection molding method and which has been subjected to degreasing to obtain a degreased body forming the nozzle tip outer surface member. The degreased body forming the nozzle

tip outer surface member is superimposed on the degreased body forming the nozzle body to cover the tip outer surface side of the degreased body forming the nozzle body and is subjected to diffusion sintering to thereby integrally unite them. It is preferable that a hot isostatic pressing operation be performed after the diffusion sintering.

Fig. 2



## Description

## Technical Field

**[0001]** The present invention relates to a fuel injection nozzle for an internal combustion engine and particularly to a fuel injection nozzle which is suitable for a diesel engine among internal combustion engines, is superior in durability and is inexpensive, to a nozzle blank and to a method of producing the nozzle blank.

## Background Art

**[0002]** A fuel injection nozzle 1 disposed in the combustion chamber of an internal combustion engine such as those used for ships conventionally contains a nozzle head (nozzle) 2 formed with an injection hole 2a on one end thereof and with a valve seat 4 of the needle valve 3 on the other end, and a needle valve 3 arranged so as to be abutable onto the valve seat 4 of the nozzle head (nozzle) 2 and is configured to be able to inject fuel supplied from a fuel tank (not shown) through a fuel channel 1a, from the injection hole 2a at a predetermined timing. This is the reason why the nozzle head (nozzle) 2 has been produced using, for example, high-speed tool steel SKH51 in consideration of heat resistance and erosion resistance so far.

**[0003]** However, a nozzle head (nozzle) like this lacks in durability under the severe working condition associated with recent developments of high-performance engines and it is greatly desired to improve the durability of the nozzle head (nozzle) with the intention of further prolonging life.

To cope with such a desire, Patent Document 1 proposes a fuel injection nozzle for a diesel engine which can improve the life of a nozzle tip (nozzle). In the techniques described in Patent Document 1, the nozzle tip (nozzle) is formed of a high-Ni-Cr-Al alloy, the nozzle tip (nozzle) and the valve seat are separately formed, and the valve seat is formed of a material having a higher hardness than that of the nozzle tip (nozzle) (see, FIGS. 1 and 2). Further, in the techniques described in Patent Document 1, there is the description that it is preferable that further the top end part and the base end part be separately formed wherein the top end part to be exposed to the inside of the combustion chamber is formed of a high-Ni-Cr-Al alloy, the base end part covered with an adapter cap be formed of a material having a higher hardness than that of the nozzle tip, and the both are metallurgically joined with each other to integrate. It is described in Patent Document 1 that according to these techniques, the life of the nozzle tip (nozzle) can be significantly prolonged.

**[0004]** Further, Patent Document 2 proposes a nozzle head (nozzle) for injection nozzle head made of mechanical alloying chromium-nickel steel alloyed with C, Al, Ti, Fe, N, O and yttrium oxide. According to the techniques described in Patent Document 2, the nozzle head (nozzle) has duration twice that of a conventional nozzle head (nozzle) even under a corrosive, chemical and thermal environment such as that in a combustion chamber of an internal combustion engine such as a diesel engine. Patent Document 2 also reveals that when the a nozzle head (nozzle) for injection nozzle is produced from an alloy being called under the name of "INCONEL ALLOY MA758" (trademark), the duration of the nozzle head becomes two or three times longer than before.

**[0005]** In the techniques described in Patent Documents 1 and 2, at least the top part of the nozzle head (nozzle) for injection nozzle which is exposed to the inside of the combustion chamber of the internal combustion engine is made of a high-Ni-Cr-Al alloy or mechanical alloying chromium-nickel steel to improve the durability of the nozzle head (nozzle) for injection nozzle. Then, in the techniques described in Patent Document 1, it is preferable that the top end part and the base end part are separately formed of materials different from each other and integrated with each other by metallurgical bonding such as welding and pressure welding.

**[0006]** Further, a fuel injection nozzle having a form as shown in FIG. 8 is described in Patent Document 5. A fuel injection nozzle 1 described in Patent (Document) 5 contains a base body (center member) 2b which is a unit body and a nozzle head (nozzle) 2, the lower end terminal of which is coated with a coating (covering) 2c. In the major axis direction of the base body 2b, a major axis direction hole is formed which includes an upper region, a pressure chamber disposed below the upper region for hydraulic actuation of a nozzle needle (needle valve) 3 and a lower region disposed below the pressure chamber. In the techniques described in Patent Document 5, the coating (covering) 2c is formed of a high temperature-corrosion resistance alloy. In this case, the high-temperature corrosion resistance-alloy is suitably bonded with the base body by the laser application method, plasma spraying, welding or powder metallurgy joining or the like.

**[0007]** As a method of producing a nozzle having a structure using a combination of different materials like this, a method of producing a nozzle using, for example, a joint utilizing brazing has been recently proposed instead of using the method in which the tip part and the base end part are separately formed to integrate the both by metallurgical bonding such as welding and pressure welding.

For example, a nozzle having a form as shown in FIG. 6 is described in Patent Document 3. The nozzle 2 described in Patent Document 3 is one containing a center member 2b including a center and longitudinal channel communicated with a number of nozzle holes (injection holes 2a) and a lower part and a covering 2c enclosing the lower part of the center member, wherein the center member 2b and the covering 2c are alternately brazed. Then, in the techniques

described in Patent Document 3, the covering 2c is constituted of a corrosion-resistance alloy and the center member 2b is constituted of a ferrous alloy having a fatigue strength of  $\pm 500$  MPa. This ensures that a long-life nozzle can be provided. In the techniques described in Patent Document 3, a needle valve 3 supports a ring-shaped blockade piece 3a that quickly closes the injection holes 2a when the injection is finished. However, the techniques described in Patent Document 3 have the problem that the brazing process is complicated, bringing about reduced productivity.

**[0008]** Further, a fuel valve nozzle for a diesel engine having a form as shown in FIG. 7 is described in Patent Document 4. The nozzle described in Patent Document 4 has a structure in which the outside region (covering) 2c is constituted of a first material essentially composed of a first alloy having corrosion-resistance, a region (center member) other than the outside region is constituted of a second material essentially composed of a second alloy, and the boundary region between these regions is constituted of a material having a solid structure (integrated structure) free from the presence of micro cracks. In the techniques described in Patent Document 4, it is preferable to use a corrosion-resistance alloy as the first alloy and an alloy having higher fatigue strength compared to the first alloy as the second alloy.

#### CITATION LIST

Patent Document

#### **[0009]**

Patent Document 1: Japanese Utility Model Application Laid-Open (JP-U) No. 1-134773.

Patent Document 2: Japanese Patent Application Laid-Open (JP-A) No. 7-19147

Patent Document 3: Japanese Patent Application National Publication No. 2005-537438

Patent Document 4: Japanese Patent Application National Publication No. 2006-502334

Patent Document 5: JP-A No. 2000-73919

#### SUMMARY OF THE INVENTION

##### Problems to be Solved by the Invention

**[0010]** Patent Document 4 shows a method utilizing powder metallurgy as shown, for example, in FIG. 4 as an example of the method of producing a nozzle in which the tip part has a two-layer structure constituted of different materials.

A core member (core material) 10 forming a region other than the outer surface region (nozzle tip outer surface side of the nozzle) of the nozzle is formed by molding into a predetermined form (form similar to that of the internal surface side material 22 of the nozzle 2 which is to be a finished product) in advance by using, for example, a melting material made of a second alloy. Then, the molded core member (core material) 10 is inserted into a mold (container) 100. The mold 100 is constituted of a bottom wall 14, a side wall 15, a cover 16 and a filling nozzle 17. Then, a first alloy powder for constituting the outside region (nozzle tip outer surface side) of the nozzle is filled into a cavity around the core member (core material) 10 in the mold (container) 100 via the filling nozzle 17. Then, the air inside of the mold is sucked and is air-tightly sealed as needed. Thereafter, the mold 100 is heated to a predetermined temperature to perform hot isostatic press treatment (HIP treatment) accompanied with sintering, thereby solidifying the compact or green body to form a condensed body free from any pore, resulting in the formation of a nozzle blank in which the tip part has a two-layer structure constituted of different materials. This nozzle blank is mechanically processed to obtain a nozzle 2 (finished product) having a desired shape.

**[0011]** In this method, however, a lot of an expensive material constituting the covering (nozzle tip outer surface side member) 21 is used and it is necessary to remove a large part of the expensive material by mechanical processing, giving rise to the problem concerning increased material cost and rise in the cost required for producing a fuel injection nozzle. Further, most of the materials constituting the covering (nozzle tip outer surface side member) are processing-resistant materials which are so hard that they can be processed with difficulty, posing the problem that it takes long time to carry out mechanical processing and the productivity of a fuel injection nozzle is lowered.

**[0012]** It is an object of the present invention to solve the above prior art problems and to provide an internal combustion engine injection nozzle which is applicable to an internal combustion engine fuel injection nozzle having a form as shown in at least FIGS. 6 to 8, and is produced in a simple production process with high productivity at low cost highly precisely, a nozzle blank and a method of producing the nozzle blank. The nozzle which is a subject of the present invention is used as fuel injection nozzles for internal combustion engines and especially, diesel engines. The diesel engine is preferably a 2-stroke crosshead engine though it may be a 4-stroke crosshead engine. This engine is frequently operated using heavy fuel oil even containing sulfur. For this, it is exactly required for the nozzle used in this engine to have long life.

## Means for Solving the Problem

**[0013]** The inventors of the present invention thought of application of the metal injection molding method (MIM method) to attain the above object. Then, the inventors of the present invention have conceived the idea that the MIM method was applied to constitute a nozzle containing a nozzle body 22 and a nozzle tip outer surface side member 21 that covers the tip outer surface side of the nozzle body, wherein the nozzle tip outer surface side member 21 is made of a material different from that of the nozzle body 22 and is formed by molding separately from the nozzle body. It was found that if the both were then superimposed on (combined) and bonded with each other to integrate the both, the both could be formed into a near net shape close to that of a finished product by one molding and bonding process, ensuring that material costs and mechanical processing costs were reduced and also, the productivity was significantly improved. The present invention was completed by making studies repeatedly based on the above findings. Specifically, the gist of the present invention is as follows.

**[0014]**

(1) A nozzle blank for an internal combustion engine fuel injection nozzle, containing: a nozzle body and a nozzle tip outer surface side member which is formed of a material different from that of the nozzle body and arranged so as to cover the tip outer surface side of the nozzle body, wherein the nozzle body is formed by molding according to the metal injection molding method, the nozzle tip outer surface side member is formed by molding according to the metal injection molding method separately from the nozzle body, and the nozzle body and the nozzle tip outer surface side member are superimposed on each other and bonded with each other to integrate the both.

(2) In (1), the nozzle blank for an internal combustion engine (fuel injection nozzle), wherein the nozzle body is made of a hot die alloy tool steel or a high speed tool steel and the nozzle tip outer surface side material is made of a Ni-base super alloy.

(3) A fuel injection nozzle for an internal combustion engine, containing: the nozzle blank according to (1) or (2), the nozzle blank being further formed with predetermined injection holes and center hole by finish processing.

(4) A method of producing a nozzle blank for an internal combustion engine fuel injection nozzle, the nozzle blank being provided with a nozzle body and a nozzle tip outer surface side member which is formed of a material different from that of the nozzle body and arranged so as to cover the tip outer surface side of the nozzle body, containing: forming the nozzle body into a predetermined shape by molding according to the metal injection molding method to make a nozzle body-green body, subjecting the nozzle body-compact or green body to a debinding process to make a nozzle body-debound material, separately forming the nozzle tip outer surface side member into a predetermined shape by molding according to the metal injection molding method to make a nozzle tip outer surface side member-green body, then subjecting the nozzle tip outer surface side member-green body to a debinding process to make a nozzle tip outer surface side member-debound material, arranging these debound materials by superimposing these debound materials on each other so as to cover the tip outer surface side of the nozzle body-debound material with the nozzle tip outer surface side member-debound material, and then diffusion-sintering to bond and integrate the both to make a nozzle blank for an internal combustion engine fuel injection nozzle.

(5) In (4), the method of producing a nozzle blank for an internal combustion engine fuel injection nozzle, further containing carrying out hot isostatic press treatment after the diffusion sintering.

(6) In (4) or (5), the method of producing a nozzle blank for an internal combustion engine fuel injection nozzle, wherein a bonding coating agent is applied to the joint interface between the nozzle tip outer surface side member-debound material and the nozzle body-debound material in advance prior to the diffusion sintering.

(7) In (6), the method of producing a nozzle blank for an internal combustion engine fuel injection nozzle, wherein the bonding coating agent is a paste-like coating solution prepared by diluting the same type metal powder as that constituting the nozzle body or the nozzle tip outer surface side member and a water-soluble paste with water.

(8) In any one of (4) to (7), the method of producing a nozzle blank for an internal combustion engine fuel injection nozzle, wherein the nozzle body is made of hot die alloy tool steel or high speed tool steel and the nozzle tip outer surface side member is made of a Ni-base super alloy.

## Effects of the Invention

**[0015]** According to the present invention, compact or green bodies made of different materials are each formed separately by molding into a near-net shape close to a finished material (product) by the MIM method and are then superimposed on and bonded to each other to integrate the both. Therefore, the subsequent mechanical processing process can be shortened and an internal combustion fuel injection nozzle which has high dimensional accuracy and has a two-layer structure constituted of different materials with high productivity at low costs, showing that the present invention produces industrially outstanding effects.

## Brief Description of the Drawings

**[0016]**

FIG. 1 is an explanatory view schematically showing an example of the sectional shape of a nozzle blank according to the present invention.

FIG. 2 is an explanatory view schematically showing a production process of a nozzle blank according to the present invention.

FIG. 3 is an explanatory view schematically showing an example of a preferable sectional shape of the structure of a joint part of a nozzle blank according to the present invention.

FIG. 4 is an explanatory view schematically showing an example of a production process of a conventional nozzle blank.

FIG. 5 is a sectional view showing an example of the structure of an internal combustion engine fuel injection nozzle.

FIG. 6 is a sectional view showing an example of the structure of an internal combustion engine fuel injection nozzle.

FIG. 7 is a sectional view showing an example of the structure of an internal combustion engine fuel injection nozzle.

FIG. 8 is a sectional view showing an example of the structure of an internal combustion engine fuel injection nozzle.

## Mode for Carrying Out the Invention

**[0017]** A nozzle blank 20 for an internal combustion engine fuel injection nozzle according to the present invention used for an internal combustion engine fuel injection nozzle has, as shown in FIG. 1, a structure containing a nozzle body 22 and a nozzle tip outer surface side member 21 arranged so as to cover the tip outer surface side of the nozzle body 22. The tip part of the nozzle presents a metallurgical bonded state at the interface between the nozzle body 22 and the nozzle tip outer surface side member 21.

Because the tip part of the nozzle 2 is arranged so as to be exposed to the inside of the combustion chamber of the internal combustion engine, it is exposed to erosion-like, chemical and thermal load. The tip part of the nozzle blank 20 is covered with the nozzle tip outer surface side member 21 made of a material which is different from that of the nozzle body 22 and is superior in heat resistance, corrosion resistance and erosion resistance. Examples of the material superior in heat resistance, corrosion resistance and erosion resistance include Ni-base super alloys, Co-base super alloys, Fe-base super alloys, and the like. Examples of the Ni-base super alloys may include an INCONEL 625 ALLOY, INCONEL 686 alloy, and the like. Examples of the Co-base super alloy may include a S-816 alloy, and the like. Examples of the Fe-base super alloy may include an INCONEL 800 ALLOY, and the like.

**[0018]** The above INCONEL 625 ALLOY preferably has a composition (mass%) of 0.1% or less of C, 0.5% or less of Si, 0.5% or less of Mn, 20.0 to 23.0% of Cr, 8.0 to 10.0% of Mo, 3.15 to 4.15% of Nb and 5% or less of Fe, which is balanced with Ni and unavoidable impurities. INCONEL 625 ALLOY may further contain 0.4% or less of Ti and 0.4% or less of Al. In the case of using the MIM method, Ti and Al are not preferably added though they may exist as unavoidable impurities. In this case, 0.15% or less of Ti and 0.1% or less of Al are allowable as unavoidable impurities.

**[0019]** Further, a needle valve slides and is seated on the valve seat repeatedly inside of the nozzle body 22 and it is preferable that the nozzle body 22 be made of a material having high wear resistance. Examples of the material having high wear resistance include hot die alloy tool steel such as SKD 61 prescribed in JIS G 4404-2006 and high speed tool steel such as SKH51 prescribed in JIS G 4403-2006, alloys such as TRIBALLOY and Stellite, and the like.

**[0020]** In order to improve bonding strength by increasing the joint area between the nozzle body 22 and the nozzle tip outer surface side member 21, the joint part between the nozzle body 22 and the nozzle tip outer surface side member 21 may have any of the various shapes shown in FIG. 3. Although the nozzle blank 20 shown in FIGS. 1 is made to have the joint shape shown in FIG. 3(a), it may have a shape as shown in FIGS. 3(b) to 3(d) with the view of further increasing the joint area. Further, when it is intended to make the joint part have a linear shape in section, it is considered to adopt a joint part shape as shown in FIG. 3(e). However, this joint part shape reduces the joint area though it brings about processing easiness, and therefore, the joint part is more preferably designed to have a shape as shown in FIG. 3(f).

**[0021]** The nozzle blank 20 according to the present invention is produced by superimposing and combining the nozzle body 22 and nozzle tip outer surface side member 21 which are separately formed into near net shapes by molding according to the metal injection molding method, and by bonding the both by diffusion sintering to integrate the both. Then, it is, of course, needless to say that the nozzle body 22 and the nozzle tip outer surface side member 21 are metallurgical firmly bonded with each other at the interface between the both.

Next, a preferable method of producing a nozzle blank according to the present invention will be explained.

**[0022]** First, the nozzle body 22 and the nozzle tip outer surface side member 21 are respectively formed into a predetermined shape (sectional view) as shown in FIG. 2 by molding according to the metal injection molding method to obtain a nozzle body-green body (A) and a nozzle tip outer surface side green body (B). As the metal injection molding method, the usual metal injection molding method (MIM) may be applied to each material.

In the metal injection molding method, a plasticized kneaded material obtained through a kneading step of mixing a metal powder, and further an alloy powder such as a carbon powder and a binder under heating and pressure and a crushing step of crushing the cooled and solidified kneaded material is molded by injection molding in a die processed into a predetermined shape, followed by cooling to solidify the plasticized kneaded material, thereby obtaining a metal injection molding article having a predetermined shape.

**[0023]** As the metal powder to be used, any metal powder produced by the water-atomization method or gas-atomization method is suitably used. The nozzle body is preferably made of hot die alloy tool steel such as SKD 61 prescribed in JIS G 4404-2006, high speed tool steel such as SKH51 prescribed in JIS G 4403-2006, or a powder of a material having excellent wear resistance such as TRIBALLOY and Stellite. Further, the nozzle tip outer surface side member is preferably made of a powder of Ni-base super alloys, Co-base super alloys, or Fe-base super alloys which are materials superior in heat resistance, corrosion resistance and erosion resistance. In this case, a carbonyl powder of iron or Ni may be used in place of the water-atomization powder and gas-atomization powder to prepare an intended material composition.

**[0024]** In this case, any usual binder for metal injection molding may be applied as the binder to be used. The binder to be used is preferably one obtained by formulating a wax component, plastic component and further vegetable oil. The wax component is a component primarily extracted in debinding treatment and no particular limitation is imposed on its type. However, preferable example of the wax component includes paraffin wax, microcrystalline wax, and the like.

**[0025]** Further, though examples of the plastic components to be blended include thermoplastic resins such as a polypropylene, polyethylene, atactic polypropylene, and ethylene-vinyl acetate copolymer (EVA), a polypropylene or polyethylene is preferably used from the viewpoint of moldability and production cost.

The vegetable oil is preferably nondrying oil. Examples of the nondrying oil may include peanut oil, castor oil, olive oil and salad oil. The vegetable oil is preferably one or two or more types selected from these oils. The blending of the vegetable oil besides the wax component and plastics component within the aforementioned range brings about a drop in the solid point of the binder, an improvement in the fluidity of the binder, improvements in, for example, the affinity of the binder to the metal powder and plastic powder and a reduction in the shrinkage percentage of the green body when the green body is cooled, with the result that the occurrence of cracks in the green body is limited and also, releasability from the die is improved.

**[0026]** Then, the obtained nozzle body-green body or nozzle tip outer surface side member-green body is subjected to a debinding process to obtain a nozzle body-debound material or nozzle tip outer surface side member-debound material. The debinding process suitably used in the present invention may be any of solvent debinding treatment and heating debinding treatment. When the solvent debinding treatment is carried out, it is preferable to remove a part of the binder by the solvent debinding treatment and to remove the remainder part by the debinding sintering treatment doubling as sintering treatment. Further, as the debinding process, supercritical carbon dioxide debinding treatment may be adopted in place of the solvent debinding treatment and heating debinding treatment.

**[0027]** The nozzle tip outer surface side member-debound material which has been subjected to the debinding process is, as shown in FIG. 2, subjected to debinding process in the same manner as above after foreign substances and the like on the joined surface are removed and is arranged such that it is superimposed so as to cover the tip outer surface side of the nozzle body-debound material to obtain a laminated body (C). Then, the laminated materials of the laminated body are bonded by diffusion sintering. Thus, the nozzle tip outer surface side member-debound material and the nozzle body-debound material can be bonded and integrated with each other.

**[0028]** The temperature of the diffusion sintering is preferably in a range from 1150 to 1400°C. When the temperature of the diffusion sintering is less than 1150°C, desired diffusion sintering does not progress and therefore, desired interface bonding strength cannot be secured. At a temperature exceeding 1400°C on the other hand, crystal grains are coarsened, causing inferior mechanical characteristics. The diffusion sintering temperature is more preferably 1150 to 1300°C. The diffusion sintering is preferably carried out in a vacuum atmosphere, or in an atmosphere of inert gas such as argon or in a reduced pressure atmosphere of nitrogen gas.

**[0029]** Further, for example, in the case where clearances are generated at the boundary when the nozzle tip outer surface side member-debound material and the nozzle body-debound material are superimposed to make a laminated material (C), a bonding coating agent may be applied to the joint interface to bond and integrate the both without fail. The bonding coating agent is preferably a paste-like coating solution obtained by diluting a metal powder which is the same type as the metal powder constituting the nozzle body or nozzle tip outer surface member and a water-soluble paste with water. Here, the water-soluble paste means a material which is dissolved in water to have a paste state and indicates a material obtained by using grain starchiness as starting material to make the grain starchiness into a paste. Here, examples of the grain include wheat, rice, beans, potato, tapioca, and the like. As the starchiness paste, commercially available starch may be used without having any problem. Examples of the water-soluble paste other than the starchiness paste include PVA and the like. The blending of the paste-like coating solution is preferably a mixture containing 65 to 90 mass% of the metal powder which is balanced with 5 to 34 mass% of water and the starchiness paste.

**[0030]** The laminated material (C) is subjected to a diffusion sintering process in which the laminated materials are

bonded and integrated with each other to form an integrated body. In the present invention, it is preferable that the integrated body is further subjected to hot isostatic press treatment (hereinafter also referred to as HIP treatment). The HIP treatment performed further in succession to the diffusion sintering ensures that both materials present more firm bonding state at the interface of the both and also, the sintering density is also increased to almost 100% of the true density. The fatigue resistance of the nozzle is thereby improved and it becomes able to secure a fatigue strength which is the same as or larger than that of a melting material though the nozzle is a sintered material. In this case, the HIP treatment is preferably carried out at a treating temperature of 1000 to 1300°C under a pressure of 50 MPa or more and preferably about 100 to 200 MPa in an argon or nitrogen atmosphere. Further, the integrated body which has been subjected to the HIP treatment is preferably cooled in the furnace (furnace cooling) just after the HIP treatment from the viewpoint of improving the mechanical processability of the nozzle body. In this case, the integrated body may be cooled without furnace cooling after the HIP treatment and annealed in a separate step.

**[0031]** The nozzle blank 20 integrated in this manner is then subjected to finish processing to prepare a nozzle 2 having a desired product dimensional shape. Though the finish processing is mainly mechanical processing such as cutting processing, only a small quantity of mechanical processing is required because the nozzle blank is formed into a neernet shape by molding according to the metal injection molding method.

The nozzle blank may also be produced by bonding the nozzle body with the nozzle tip outer surface member to integrate the both by the two-color molding method of the metal injection molding method instead of producing the nozzle by forming the nozzle body and the nozzle tip outer surface member separately by molding to bond the both as a united body.

**[0032]** In the obtained nozzle blank 20, it is preferable that injection holes 2a and a center hole each having a predetermined dimensional shape be formed at predetermined positions corresponding to each type of fuel injection nozzle as shown in FIGS. 6 to 8 by finish processing including mechanical processing such as cutting processing, and the like to thereby form a nozzle 2.

The present invention will be explained in more detail by way of Examples.

## EXAMPLES

**[0033]** Two types of raw powders which were manufactured by the water-atomization method were prepared. As the raw powders, those having an average particle diameter of 5 to 15  $\mu\text{m}$  were used. One of these two types of raw powders was a SKD 61 steel powder for use as a nozzle body. Further, other raw powder was a Ni base super alloy powder for use as a nozzle tip outer surface side member. The composition of SKD 61 steel based on mass% was 0.35% C-0.97% Si-0.40% Mn-4.93% Cr-1.21% Mo-1.01% V-bal. Fe. Further, the composition of the Ni-base super alloy based on mass% was 0.02% C-0.18% Si-0.23% Mn-21.8% Cr-8.9% Mo-3.9% Nb-2.4% Fe-bal. Ni.

**[0034]** A binder was blended in this raw powder in an amount of 40% by volume and the mixture was kneaded at 120 to 180°C to prepare a kneaded product for injection molding. A wax component (PW), a plastic component (PE), and a vegetable oil component (peanut oil) were mixed and heated with stirring for use as the binder. The ratio of wax component : plastic component : vegetable oil component to be blended was designed to be 35 : 40 : 25. The kneaded material was cooled to solidify, and then, the obtained solid was crushed and poured into an injection molding machine. The temperature of the cylinder was set to 110 to 180°C to plasticize the crushed material, which was then injected into a predetermined die under a predetermined pressure (100 MPa) to produce a nozzle body-compact or green body (A) and a nozzle tip outer surface side member-compact or green body (B) each having a shape as shown in FIG. 2.

**[0035]** The obtained compact or green bodies A and B were subjected to a debinding step using solvent debinding treatment to obtain each debound material. In this case, debinding condition was as follows: temperature: 30°C, solvent: methylene chloride.

The obtained nozzle body-debound material (A) and the nozzle tip outer surface side member-debound material (B) were superimposed on each other to make a laminated material (C) as shown in FIG. 2.

Then, the laminated material (C) was heated (heating temperature: 1250°C) under reduced pressure in a nitrogen atmosphere to carry out diffusion sintering (sintering time: 2 h) at this temperature to integrate both debound materials into an integrated body. After the diffusion sintering, a part of the samples were further subjected to HIP treatment. The condition of HIP treatment was as follows: temperature: 1200°C, pressure: 117 MPa in an argon atmosphere. In a part of the examples, a bonding coating agent was applied to the interface between both materials when both materials were superimposed on each other.

**[0036]** Mechanical processing of the obtained integrated body was carried out to obtain a product having a predetermined dimension.

As a Comparative Example, a nozzle having the same dimension was produced by a conventional method as shown in FIG. 4.

With regard to the obtained integrated body (nozzle), the bonding condition of the interface was observed and a tensile test and a fatigue test were made. The test methods are as follows.

## (1) Observation of the bonding condition of the interface

**[0037]** With regard to the obtained integrated body, the section in the direction of the axis of the integrated body was observed by an optical microscope (magnification: 200 times) to evaluate the bonding condition at the joint interface. The case where clearances are observed in a range extending to a length of 2 % or more of all the length was rated as "x", the case where clearances are observed in a range extending to a length less than 2% to 0.5% or more of all the length was rated as "Δ", and the case where clearances are observed in a range extending to a length less than 0.5% of all the length was rated as "○", to evaluate the bonding condition of the interface.

## (2) Tensile test

**[0038]** The same raw powder as that of the nozzle body and the same raw powder as that of the nozzle tip outer surface side member were used and each injection-molded into a round bar by using an injection molding machine. The molded round bars were bonded with each other in the same condition as that in the bonding condition of the above integrated body. A tensile test piece was sampled from the obtained round bar and the tensile test of the sample was made to find its strength, thereby evaluating the bonding condition at the interface. In this case, the strength of the product No. 4 of Comparative Example was defined as a standard (1.0) to indicate the strength of each sample as a relative value.

## (3) Fatigue test

**[0039]** The same raw powder (SKD 61 powder) as that of the nozzle body was used and molded into a round bar by an injection molding machine, followed by debinding and sintering. A fatigue test piece (6 mmφ × parallel part 10 mm length) was cut as a sample from the round bar and a tensile-compression fatigue test (load stress: ± 700 to 1000 MPa, frequency: 10 Hz) was made to find a fatigue limit from a S-N curve. In this case, Comparative Example (product Neo. 4) was made of SKD 61 (melting material). The fatigue limit of the product No. 4 of Comparative Example was defined as a standard (1.0) to indicate the fatigue limit of each sample as a relative value. In the case of a nozzle, the nozzle body gives rise to a problem concerning fatigue strength (fatigue limit), the fatigue test was made only for the nozzle body.

**[0040]** The obtained results are shown in Table 1.

**[0041]**

[Table 1]

| Product No.                                                                                                                                                                                                                                                    | Use or nonuse of a bonding coating agent | HIP treatment | Interface bonding condition | Interface strength ratio | Fatigue strength ratio* | Overall evaluation | Remarks                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|---------------|-----------------------------|--------------------------|-------------------------|--------------------|----------------------------------|
| 1                                                                                                                                                                                                                                                              | Non-used                                 | Untreated     | Δ                           | 0.95                     | 0.95                    | Δ                  | Example of the present invention |
| 2                                                                                                                                                                                                                                                              | Non-used                                 | Treated       | ○                           | 0.98                     | 1.03                    | ○                  | Example of the present invention |
| 3                                                                                                                                                                                                                                                              | Used                                     | Treated       | ○                           | 0.99                     | 1.03                    | ○                  | Example of the present invention |
| 4                                                                                                                                                                                                                                                              | -                                        | Treated       | ○                           | 1.0                      | 1.0                     | Standard           | Comparative Example              |
| *) The fatigue strength ratio is only the results of the test made only for the nozzle head body and shows a relative value when that of Comparative Example is defined as a standard (1.0). Product No. 4 (Comparative Example) is SKD 61 (melting material). |                                          |               |                             |                          |                         |                    |                                  |

**[0042]** Each of the Examples of the present invention is equal or superior to the Comparative Example in the bonding condition of the interface and fatigue strength and is found to be more outstandingly improved than the Comparative

Example in productivity and cost.

Explanation of Letters or Numerals

5 **[0043]**

- 1 Fuel injection nozzle
- 1a Fuel passage
- 2 Nozzle
- 10 2a Injection hole
- 2b Center member (region other than the outer region)
- 2c Covering (outer region)
- 20 Nozzle blank
- 21 Nozzle tip outer surface side material (covering)
- 15 22 Nozzle body (core material)
- 3 Needle valve
- 3a Blockade piece
- 4 Valve seat for needle valve (valve seat)
- 10 Core material
- 20 14 Bottom wall
- 15 Side wall
- 16 Cover
- 17 Filling nozzle
- 100 Container (mold)

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## Claims

- 30 1. A nozzle blank for an internal combustion engine fuel injection nozzle, comprising: a nozzle body and a nozzle tip outer surface side member which is formed of a material different from that of the nozzle body and arranged so as to cover the tip outer surface side of the nozzle body, wherein the nozzle body is formed by molding according to the metal injection molding method, the nozzle tip outer surface side member is formed by molding according to the metal injection molding method separately from the nozzle body, and the nozzle body and the nozzle tip outer surface side member are superimposed on each other and bonded with each other to integrate the both.
- 35
- 2. The nozzle blank for an internal combustion engine fuel injection nozzle according to Claim 1, wherein the nozzle body is made of a hot die alloy tool steel or a high speed tool steel and the nozzle tip outer surface side material is made of a Ni-base super alloy.
- 40
- 3. An internal combustion engine fuel injection nozzle, comprising: the nozzle blank according to Claim 1 or 2, the nozzle blank being further formed with predetermined injection holes and center hole by finish processing.
- 45
- 4. A method of producing a nozzle blank for an internal combustion engine fuel injection nozzle, the nozzle blank being provided with a nozzle body and a nozzle tip outer surface side member which is formed of a material different from that of the nozzle body and arranged so as to cover the tip outer surface side of the nozzle body, comprising: forming the nozzle body into a predetermined shape by molding according to the metal injection molding method to make a nozzle body-green body, subjecting the nozzle body-green body to a debinding process to make a nozzle body-debound material, separately forming the nozzle tip outer surface side member into a predetermined shape by molding according to the metal injection molding method to make a nozzle tip outer surface side member-green body, then subjecting the nozzle tip outer surface side member-green body to a debinding process to make a nozzle tip outer surface side member-debound material, arranging these debound materials by superimposing these debound materials on each other so as to cover the tip outer surface side of the nozzle body-debound material with the nozzle tip outer surface side member-debound material, and then diffusion-sintering to bond and integrate the both to make a nozzle blank for an internal combustion engine fuel injection nozzle.
- 50
- 55
- 5. The method of producing a nozzle blank for an internal combustion engine fuel injection nozzle according to Claim 4, the method further comprising carrying out hot isostatic press treatment after the diffusion sintering.

6. The method of producing a nozzle blank for an internal combustion engine fuel injection nozzle according to Claim 4 or 5, wherein a bonding coating agent is applied to the joint interface between the nozzle tip outer surface side member-debound material and the nozzle body-debound material in advance prior to the diffusion sintering.

7. The method of producing a nozzle blank for an internal combustion engine fuel injection nozzle according to Claim 6, wherein the bonding coating agent is a paste-like coating solution prepared by diluting the same type metal powder as that constituting the nozzle body or the nozzle tip outer surface side member and a water-soluble paste with water.

8. The method of producing a nozzle blank for an internal combustion engine fuel injection nozzle according to any one of Claims 4 to 7, wherein the nozzle body is made of hot die alloy tool steel or high speed tool steel and the nozzle tip outer surface side member is made of a Ni-base super alloy.

Fig. 1

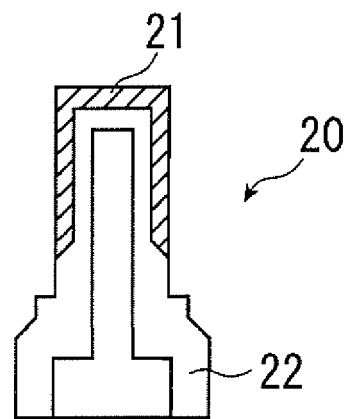


Fig. 2

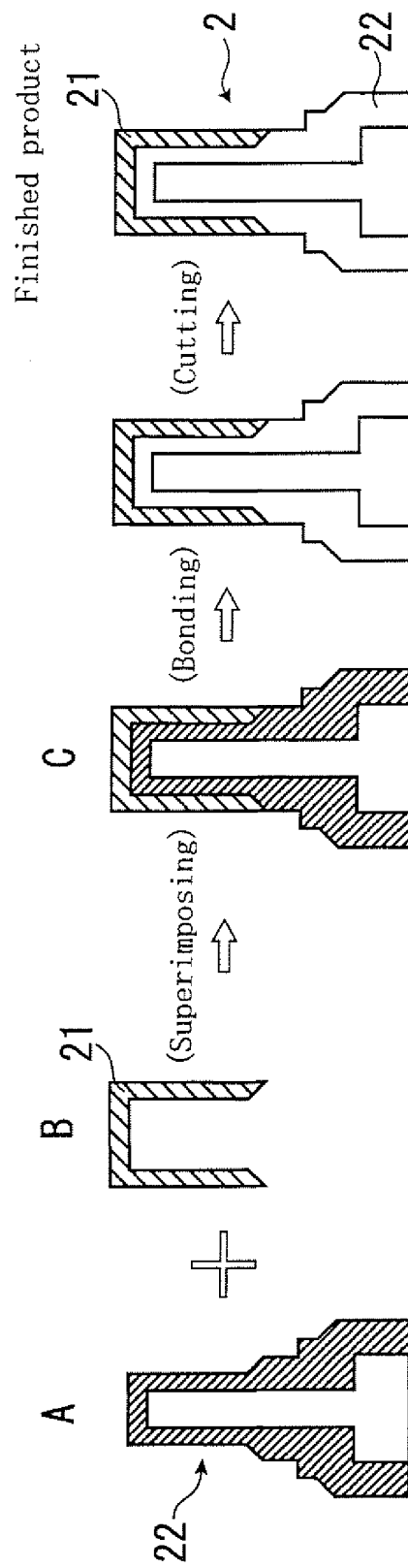


Fig. 3

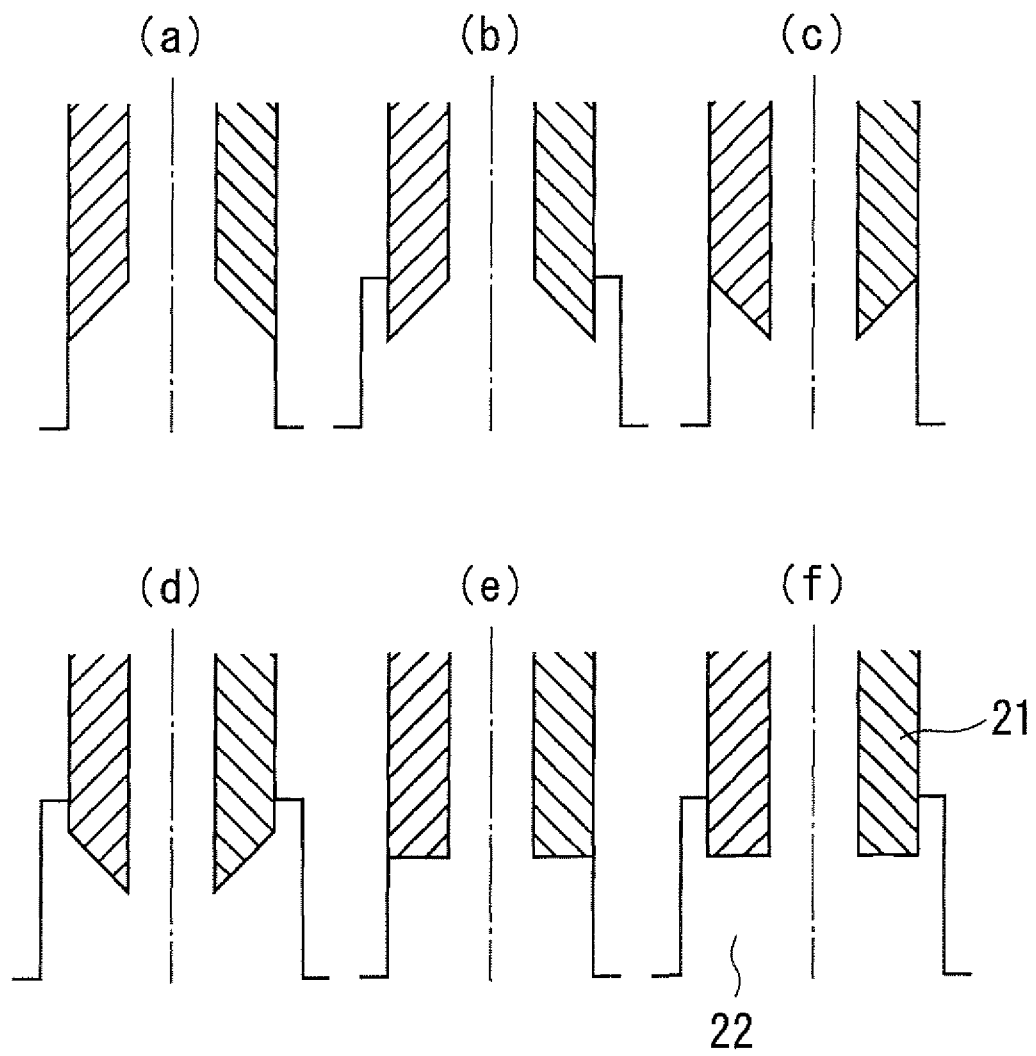


Fig. 4

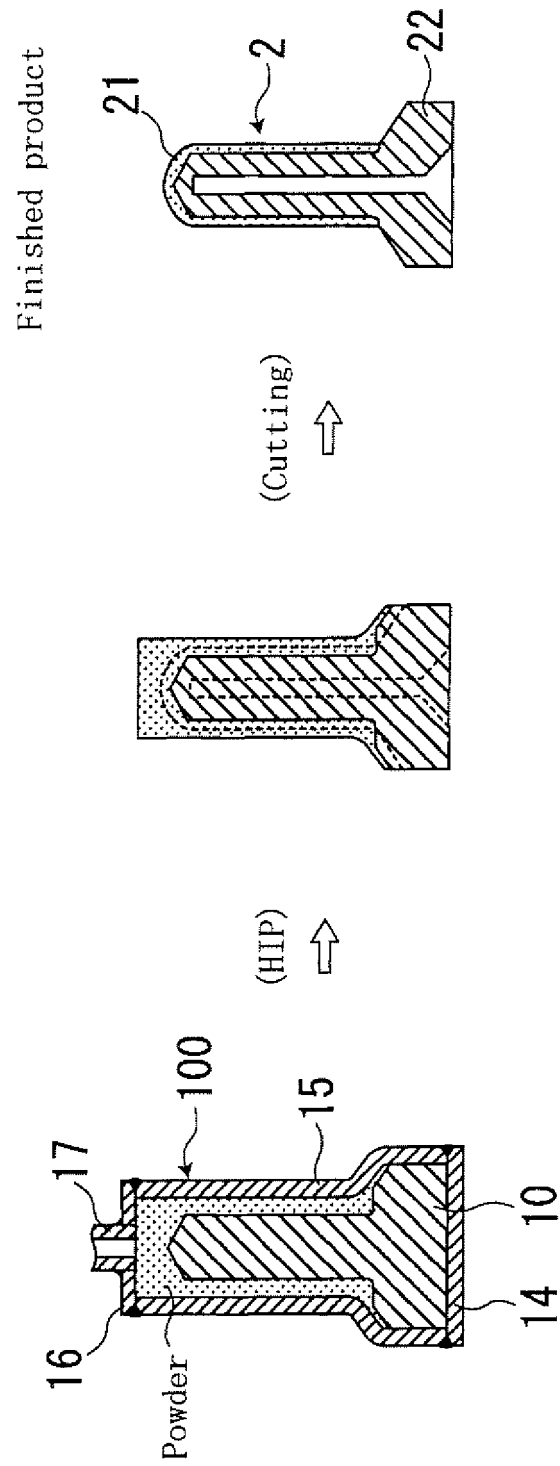


Fig. 5

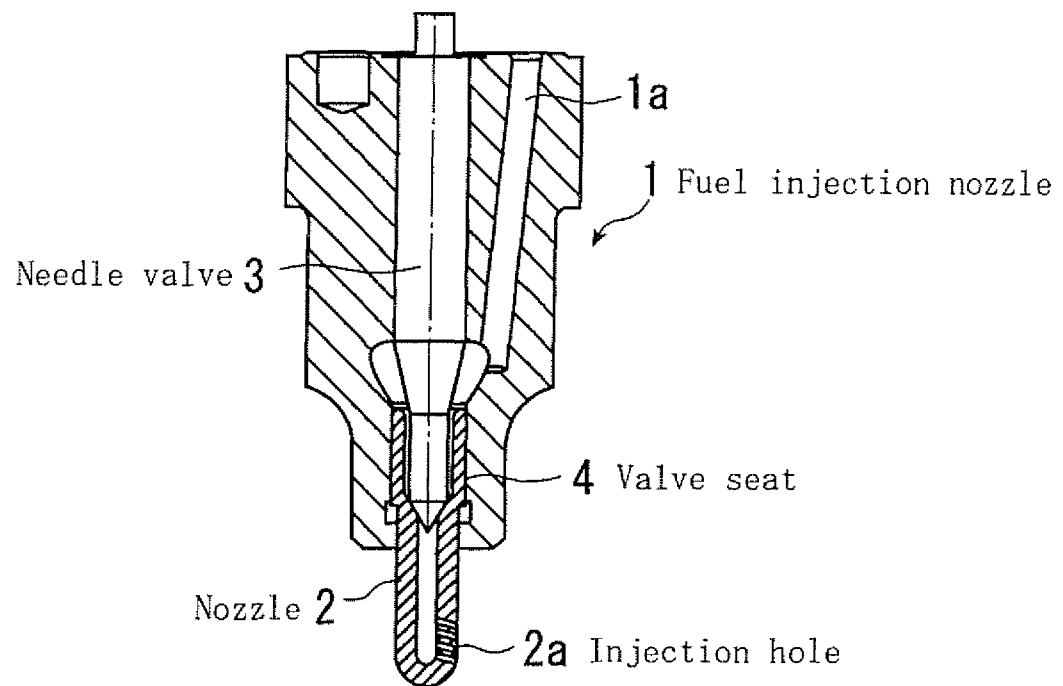


Fig. 6

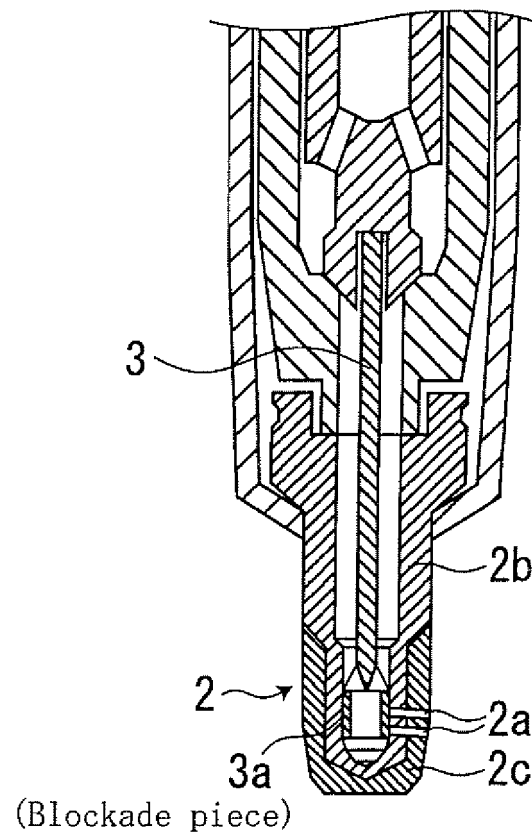


Fig. 7

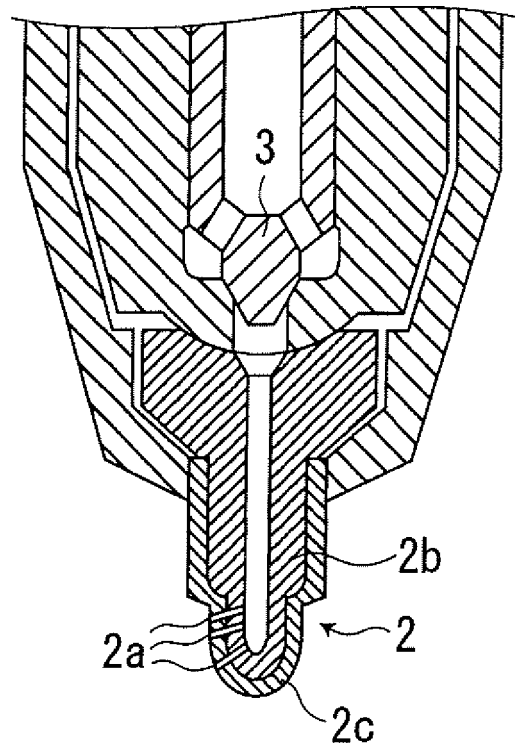
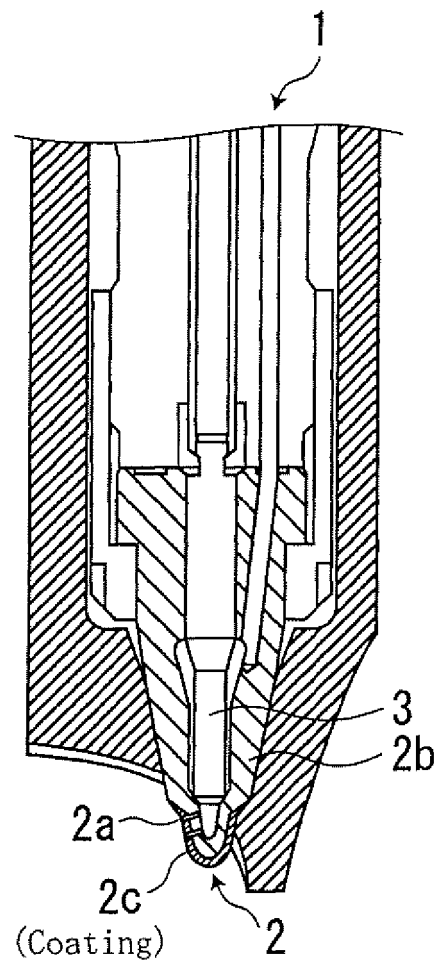


Fig. 8



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/061054

## A. CLASSIFICATION OF SUBJECT MATTER

F02M61/18(2006.01)i, B22F3/02(2006.01)i, B22F3/15(2006.01)i, B22F7/06(2006.01)i, F02M61/16(2006.01)i, C22C19/05(2006.01)n, C22C38/00(2006.01)n, C22C38/24(2006.01)n

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)

F02M61/18, B22F3/02, B22F3/15, B22F7/06, F02M61/16, C22C19/05, C22C38/00, C22C38/24

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 1996-2010  
Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010

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. |
|-----------|---------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y<br>A    | JP 2005-537438 A (MAN B & W DIESEL A/S),<br>08 December 2005 (08.12.2005),<br>paragraphs [0022] to [0037]; fig. 1 to 4          | 1-3<br>4-8            |
| Y<br>A    | WO 2007/097583 A1 (HPM Technology Co., Ltd.),<br>30 August 2007 (30.08.2007),<br>page 5, line 1 to page 6, line 23; fig. 1 to 2 | 1-3<br>4-8            |
| A         | JP 2006-502334 A (MAN B & W DIESEL A/S),<br>19 January 2006 (19.01.2006),<br>paragraph [0041]; fig. 1 to 2                      | 5-8                   |



Further documents are listed in the continuation of Box C.



See patent family annex.

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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  
30 August, 2010 (30.08.10)

Date of mailing of the international search report  
07 September, 2010 (07.09.10)

Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
PCT/JP2010/061054

|                   |            |                                                                                                                                                                              |
|-------------------|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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**REFERENCES CITED IN THE DESCRIPTION**

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- JP 7019147 A [0009]
- JP 2005537438 A [0009]
- JP 2006502334 A [0009]
- JP 2000073919 A [0009]