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(54) Title: A METHOD FOR MANUFACTURING A FUEL NOZZLE BLANK WITH A METALLIC CLADDING

(57) Abstract: A method for manufacturing a metallic body (50) having a core (5) and metallic cladding (60) by Hot Isostatic Pressing, comprising the following steps: - providing a hollow body (2) that comprises a bottom wall (3), a core (5) and a lateral wall (4), wherein the hollow body is filled with cladding material (8); - Providing the bottom wall (3) and the top wall (9) of the hollow body (2), prior to the step of HIP, with at least one centering means (11, 12) for centering the final body (20) obtained in the step HIP in a metal machining apparatus (30).

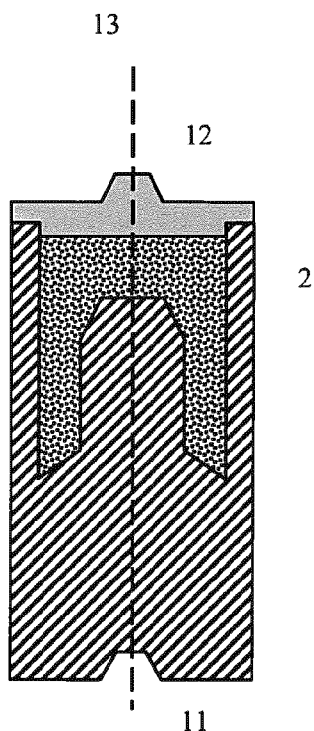


Figure 4



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A method for manufacturing a fuel nozzle blank with a metallic cladding

TECHNICAL FIELD

The present invention relates to a method for manufacturing a metallic body having a
5 cladding according to the preamble of claim 1.

BACKGROUND ART

Hot Isostatic Pressing (HIP) is a conventional method for manufacturing components of
metallic material. The method allows for manufacturing of complex components in near-net
shape and also for integration of different materials in the same product. In HIP, a steel
10 capsule which defines the final shape of the component is filled with metallic powder and
thereafter subjected to high temperature and high pressure so that the particles of the
metallic powder bond into a solid component.

Hot Isostatic Pressing may be used to apply claddings of metallic materials onto pre-
manufactured cores. WO2004/030850A1 describes a method for manufacturing fuel valve
15 nozzles. According to the method, a metallic tube section is arranged to form a space
around a pre-forged nozzle core. The space is filled with metallic powder and the
arrangement is enclosed in a capsule and subjected to HIP so that the metallic powder, the
core and the tube section bond into a solid component.

A similar method for manufacturing a valve nozzle is described in Applicants European
20 Patent Application EP12173411. This method comprises the steps of forming a solid blank
in a metal machining operation into a hollow body which comprises a bottom wall from
which a core extends and a lateral wall which encloses a space around core. The space is
filled with metal cladding material and closed by an upper wall and subsequently subjected
to HIP.

25 After HIP the solid components are typically subjected to machining in order to expose the
cladding on the core. Typically, machining is performed by turning or milling.

However, often the final consolidated component is deformed during the HIP process. This causes a problem in the machining of the component since it becomes difficult to accurately clamp and center the component in the machining apparatus. As a consequence thereof, the cladding may not be machined to an accurate thickness. A further drawback with the prior art is that the machining of the components is time consuming and costly due to cumbersome manual labor and a poor yield of acceptable components.

Consequently, it is an object of the present invention to present an improved method which allows for manufacturing by HIP of metallic components having a cladding whereby the cladding on the final components has very low thickness variation. A further object of the present invention is to achieve a cost effective method for manufacturing of metallic components having a cladding. Yet a further object of the present invention is to present a method for manufacturing of metallic component having a cladding whereby the method can be performed in short time and with little effort.

SUMMARY OF THE INVENTION

According to a first aspect of the invention at least one of the above objects is achieved by a method for manufacturing a metallic body 50 having a core 5 and metallic cladding 60, comprising the following steps:

- providing at least one a hollow body 2 that comprises a bottom wall 3, a core 5 that extends from the bottom wall 3 and a lateral wall 4 that extends from said bottom wall 3 and encloses the core 5 so that an inner space 6 is formed around the core 5;
- filling the inner space 6 with a metallic cladding material 8;
- closing the inner space 6 by arranging a top wall 9 on the lateral wall 4;
- positioning the filled hollow body 2 in a capsule 10 and evacuating air from the capsule (10) and sealing the capsule 10;

- subjecting the capsule 10 to Hot Isostatic Pressing (HIP) at a predetermined temperature, a predetermined pressure and for a predetermined time so that the cladding material 8 and the hollow body 2 bond and forms a solid body 20;

5 - machining the solid body 20 in a metal machining apparatus 30, wherein at least a portion of the lateral wall 4 is removed and the exposed cladding material 8 is machined to a cladding 60 of a predetermined thickness; characterized in that the bottom wall 3 and the top wall 9 of the hollow body 2, prior to the step of Hot Isostatic Pressing, each are provided with at least one centering means 11, 12 for centering the final body 20 obtained in the step of Hot Isostatic Pressing in the metal machining apparatus 30.

10 By providing the centering means in the hollow body prior to the step of Hot Isostatic Pressing it is possible to accurately center the HIP:ed solid body in a metal machining apparatus with respect to the center of core of the solid body, even if the solid body is deformed during HIP. By subsequently machining the cladding to a predetermined thickness which is determined as a distance from the center of the core, the thickness of the
15 cladding around the core may be held within a very narrow tolerance range.

The principle of invention is further explained with reference to figure 8. Figure 8 shows schematically a longitudinal cross-section of a solid HIP:ed component 20 comprising a hollow body 2 comprising a bottom wall 3, an upper wall 9 and a core 5. The core 5 is embedded in a cladding material 8. A capsule 10 surrounds the solid body. Centering
20 means 11, 12 in the form of a protruding truncated cone and a truncated cone recess are provided in the bottom and upper walls 3, 9.

Figure 8, indicates schematically the deformation that has occurred during the HIP process. This deformation is to a certain extent often anisotropic and in particularly in the case of elongated cylindrical components, the periphery of the HIP:ed body may be unevenly
25 deformed.

It should however be appreciated that figure 8 is schematic and that the anisotropic nature of the deformation is strongly exaggerated for illustrative reason. In reality the deformation is also much more complicated.

5 According to the invention, the centering means 11 and 12 are applied prior to HIP in the center of the bottom and upper walls 3, 9 of the hollow body (position X1). During densification, the periphery of the capsule 10 and the solid body 20 is deformed anisotropic in radial direction as indicated in figure 8. However, the positions of the centering means 11, 12 are not affected by the deformation. When the solid body subsequently is subjected to a machining operation in the form of turning in a lathe, the solid body 2 may be centered
10 along the line X1 by corresponding centers in the metal machining apparatus. The solid body 2 will then be centered with respect to the true center of the core 5 and the machining operation will yield a cladding with a very small thickness variation around the core.

In the case of conventional manufacturing of a clad component (which does not comprise centering means), the end of the solid body 20 is typically gripped by a chuck and
15 the solid body will therefore be centered with respect to the center of the chuck. However, since the circumference of the solid body is deformed anisotropic, the center of the chuck will not be aligned with the center of the core of the pre-manufactured body. Instead, the solid body will be centered along the line X2 which is offset from the center of the core. When the solid body is machined the offset centering will cause the solid body to rotate
20 eccentrically and cause the thickness to vary on the core.

Further embodiments and advantages of the present invention are disclosed in the dependent claims and the following detailed description.

BRIEF DESCRIPTION OF DRAWINGS

Figures 1 – 7 shows the steps of the inventive method.

25 Figure 8 shows schematically a hollow body manufactured according to the invention

Figure 9 shows a fuel valve nozzle blank that has been obtained by the inventive method.

DETAILED DESCRIPTION OF THE INVENTION

The inventive method will in the following be described in detail with reference to the manufacturing of a fuel injection nozzle blank for a diesel engine, in particular a two-stroke diesel engine. For further details it is referred to Applicants non-published European Patent Application EP12173411 which content herewith is incorporated by reference

In a first step of the method a hollow body 2 is provided. Figure 1 show schematically a side view of the hollow body 2 which is cylindrical and has a rotational symmetric form. The hollow body 2 may be manufactured in tool steel, for example AISI H13/SS2242. The hollow body 2 has a bottom wall 3 from which a core 5 and a lateral wall 4 extends. The core 5 extends from the center of the bottom wall 3 and the lateral wall 4 extends from the periphery of the bottom wall. The lateral wall 4 surrounds the core 5, i.e. is coaxial with the core 5, so that a space 6 is limited between the inner periphery of the wall 4 and the outer periphery of the core 5. In longitudinal direction the lateral wall 4 extends beyond the core 5. The inner periphery of the lateral wall 4 thereby determines the limits of the space 6 in the radial direction and the extension of the lateral wall 4 in longitudinal direction determines the upper extension of the space 6. The bottom wall 3 has an end surface 3a which is substantial flat so that the hollow body 2 may be placed upright on the bottom of a HIP capsule. An advantage by using a hollow body in the manufacturing of clad components is that that the provision of a lateral wall 4 results in a more homogenous deformation on radial direction of the hollow body during HIP. This in turn results in low thickness variation of the cladding. A further advantage is that filled hollow bodies may be prepared in advance which is favorable for efficient manufacturing of several nozzle blanks simultaneously.

According to a first alternative of the inventive method, the hollow body 2 is manufactured by machining of a solid blank of metal, i.e. a single piece of metal for example a solid cylindrical bar of steel. The solid steel blank is subjected to a metal machining operation, for example milling, in which metal is removed from the blank such that the core 5, the space 6 and the lateral wall 4 are formed in one end of the blank 1 and leaves the bottom

wall 3 in the other end of the blank. The advantage thereof is that the position of the various parts of the hollow body, i.e. the core and the bottom- and upper wall can be made very precise in relation to each other. There is further no need for auxiliary operations such as welding for attaching the parts of the hollow body to each other.

5 According to a second alternative of the inventive method, see figure 3, the hollow body 2 is formed by attaching a tube section 19 onto a preformed nozzle pre-body 1. The nozzle pre-body 1 may for example be manufactured by forging or casting, possibly in combination with machining. The nozzle-pre body comprises a core 5 and bottom wall 3. The upper portion of the bottom wall 3 comprises a shoulder 3b which surrounds the base
10 of the core 5 and provides thereby a support surface for the tube section 19. The tube section 19 is arranged so that one of its end surfaces is supported on the shoulder 3a and so that the tube section surrounds the core 5 and extends in longitudinal direction beyond the core. The tube section 19 is thereby a lateral wall 4 and forms a space 6 around the core 5. Preferably, the end of the tube section is welded to the bottom wall 3 in order to keep it in
15 stable position during HIP. This way of manufacturing the pre-manufactured body is fast and inexpensive. The tube section 19 may be manufactured in construction steel, such as 1312 (E235).

In a second step, see figure 3, the space 6 is filled with metallic cladding material 8 so that the core 5 is embedded in metallic cladding material. Preferably, the metallic cladding
20 material 8 is a metal powder. The advantage of using powder is that the space 6 thereby easily can be filled even if the core has a complicated form. The metallic cladding material 8 has a different chemical composition than the core 5. The present embodiment relates to a fuel injection nozzle and the purpose of the metallic cladding material is to provide a corrosion resistant layer on the core part of the nozzle. Therefore it is preferred that the
25 metallic cladding material consists of a nickel-based alloy, for example NiCr49Nb1 or NiCr22W6Al5 or NiCr22MoNbTi. After filling, the metallic cladding material 8 may be compacted by stamping or shaking to ensure that all voids are filled in the hollow body (not shown).

In a third step the filled hollow body 2 is closed. Thereby is a top wall 9 arranged on top of the upper end of the lateral wall 4. The top wall 9, see figure 3, comprises a lower side 9b, which is supported on the upper end of the lateral wall 4 and an upper side 9a which is directed away from the hollow body 2. The upper wall 9 is designed such that it completely covers the upper end of the hollow body 2 and thereby forms a lid which closes the hollow body. In order to allow air to be expelled from the hollow body in a later air evacuation step, the upper wall 9 shall not be sealed to the upper end of the lateral wall. 4. The top wall 9 may be manufactured in construction steel, such as 1312 (E235).

According to the invention, the bottom wall 3 and the top wall 9 of the filled hollow body 2 are provided with centering means 11 and 12 for centering the final HIP:ed body in a metal machining apparatus. Figure 4 show schematically the position of the centering means in the filled hollow body 2. A first centering means 11 is provided in the end surface 3b of the bottom wall 3 and second centering means 12 is provided in the upper side 9a of the top wall 9.

Obviously, the centering means should be provided in a position of the hollow body which is not covered by cladding material, thus free of cladding material.

Preferably, the centering means 11 and 12 are located in the center of the bottom and top wall so that they are aligned along a straight line 13 running through longitudinally through the center of the core 5 and through the both centering means 11, 12.

The centering means in both the bottom wall and the top wall of the hollow body are preferably designed to be engaged by corresponding centers in conventional metal machining apparatuses. According to the present invention, a "metal machining apparatus" also known as "metal machine tool" or "machine tool" may be a metal cutting machine such as a lathe or milling cutter. The metal machining apparatus may also be an Electrical Discharge Machining device.

Preferably, the metal machining apparatus is a lathe, i.e. an apparatus for machining steel by turning. As will be described further below the centers for lathes are so called "male centers" in form of cones or truncated cones. Alternatively, the centers in lathes are so

called “female centers” in the form of a sleeve with a conically shaped opening a.k.a “tapered sleeve”. Such centers are commercially available, for example from the company Röhm (RÖHM GmbH, Heinrich-Röhm-Straße 50, 89567 Sontheim/Brenz, Germany).

Consequently, the centering means in the hollow body are in the form of “male centering means” or “female centering means” The male centering means is a protruding element, for example in the form of a cone or a truncated cone. The female centering means is a recess i.e. a bore. For example the female centering means is in the form of a recess or a bore with the shape of a cone or a truncated cone. It is preferred that the centering means in the hollow body are complementary with commercially available centers in lathes. However, the male centering means could be a protruding element of any shape and the female centering means could be a recess of any shape.

In figure 4, a female centering means 11 in the form of a truncated cone shape recess is provided in the end surface 3a of the bottom wall 3. It is preferred to provide a female centering means in the lower end surface of the hollow body 2 since the hollow body 2 then may be placed steadily in upright position. A male centering means 12, in the form of a protruding truncated cone is provided in the upper surface 9a of the upper wall 9.

It is obvious that either a male centering means or a female centering means could be provided in the upper wall or in the bottom wall of the hollow body 2. For example, a male centering means could be provided in the bottom wall 3 and a female centering means in the upper wall 9 or vice versa. It is also possible to provide male centering means in both the bottom wall 3 and the upper wall 9. Or to provide female centering means in both the bottom wall 3 and the upper wall 9 of the hollow body 2.

Female centering means, e.g. recesses or bores, may be achieved by drilling or milling. Male centering means, for example cones, or truncated cones, may be achieved by machining of the end surface of the bottom wall or the top wall of the hollow body. It is also possible to pre-manufacture cones or truncated cones, by machining and subsequently attaching the cones by welding to the top or the bottom walls of the hollow body.

The hollow body is then placed in a capsule 10, see figure 5. The capsule is preferably a steel tube with a closed bottom end. Preferably, the steel tube is manufactured from low-carbon steel. The length of the capsule is larger than the length of at least one hollow body. However, as is shown in figure 5, a plurality of hollow bodies are typically HIP:ed simultaneously in one single capsule. The plurality of hollow bodies could be any number, such as 2 or more, 5 or more or 10 or more. For example the plurality of hollow bodies could be 2- 10 or 2- 20. The length of the capsule is therefore larger than the total length of the plurality of the hollow bodies that shall be subjected to HIP, i.e. the sum of the length of the individual hollow bodies. The wall thickness of the tubular capsule is large enough (normally at least 1 mm) to ensure that the interior of the capsule is sealed during HIP. The inner diameter of the capsule is slightly larger than the outer diameter of the hollow bodies. For example, the ratio between the inner diameter of the capsule and the outer diameter of the hollow body defined as $D_{\text{capsule}} / D_{\text{hollow body}}$ is in the range of 1 – 1.10.

With reference to figure 5, the plurality of hollow bodies 2 are stapled on top of each other in the capsule 10. To avoid bonding of adjacent hollow bodies to each other, the top and bottom surfaces 3a, 9a of the hollow bodies are provided with a coating which prevents metallurgical bonding. For example the coating is boron nitride.

There is a possibility that female centering means in the hollow bodies deforms or even closes during HIP. To avoid this, a cover piece 40 may be placed in the bottom of the capsule, prior to inserting the hollow bodies into the capsule. The cover piece 40 comprises one surface 40a which is supported on the bottom of the capsule and one surface 40b which comprises a protruding element 40c which is adopted to fit into a female centering means. In this case the protruding element 40c is truncated cone. The protruding element 40c of the cover piece 40 fills out the female centering means 11 of the first hollow body 2 in the capsule 10 and prevents the centering means 11 from deforming during HIP. Obviously, the cover piece is also provided with a boron nitride coating to prevent bonding. Further filled and closed hollow bodies are subsequently inserted into the capsule and stapled on top of each other. Thereby is the male centering means 12 of one hollow body 2 received in the female centering means 11 of the next hollow body 2. On top of the uppermost hollow

body 2, a second cover piece 40 is placed. The second end piece comprises one surface 40b which comprises a recess 40d which is adopted to receive the male centering 12 means of the uppermost hollow body. The opposite surface 40a is flat and directed towards the opening of the capsule. The arrangement of the second cover piece 40 prevents that the male centering means of the uppermost hollow body from damaging the capsule during HIP. It is obvious that the design of the cover pieces may be adapted to the centering means in the hollow bodies.

The described arrangement of placing several hollow bodies in a capsule is of course a cost effective way of manufacturing large amounts of injection nozzles. However, the described arrangement of hollow bodies with female centering means in bottom and male centering means in the top provides additional advantages. Firstly, this arrangement locks individual hollow bodies in the staple to each other and causes the staple of hollow bodies to remain relatively stable during HIP. Secondly, by the described arrangement the female centering means in one hollow body is protected from deformation during HIP by the male centering means in another hollow body. Therefore only one cover piece is needed to protect the female centering means in the lower most hollow body. This reduces cost further.

Preferably, the male centering means have the form of a truncated cone with an inclination angle of maximum 60° , preferably $40 - 60^\circ$. Preferably, the female centering means is a bore with the same shape of truncated cone, i.e. an inclination angle of maximum 60° , preferably $40 - 60^\circ$. Tests has shown that mating centering means with theses dimensions results in little or no deformation of the female centering means during HIP. Tests have also shown these dimensions prevents that the male centering means to get stuck in the female centering means during HIP. Thereby the hollow bodies may be easily separated from each other after HIP.

When all the hollow bodies have been positioned in the capsule, a lid 10b with an opening 10c is welded over the upper end of the capsule. The capsule may comprise air which is has a negative impact on the bonding of the cladding to the core. Therefore the air is evacuated from the capsule 10 by drawing a vacuum in the capsule. The vacuum is drawn through the

opening in the lid and subsequently the opening in the lid is welded shut so that the capsule is sealed.

Thereafter, the hollow body 2 is subjected to Hot Isostatic Pressing (HIP), see figure 6. The capsule with the hollow body is thereby placed in a HIP furnace 100 and subjected to a predetermined temperature, a predetermined pressure for a predetermined period of time so that the metallic cladding material, the core, the lateral wall and the top and bottom walls bond to each other into a dense and solid final body. Typically, the pressure in the furnace is in the range of 700-1100 bar, preferably, 900-1100 bar, and most preferably around 1000 bar. The temperature is selected to be below the melting point of the material with the lowest melting point. The closer the temperature is to the melting point, the higher is the risk for the formation of melted phases in which brittle streaks could be formed. However at low temperatures, the diffusion process slows down and the HIP:ed material will contain residual porosity and the metallic bond between materials become weak. Consequently, the temperature is in the range of 900-1200°C, preferably 1100-1200°C, and most preferably around 1150°C. The duration of the HIP process depends on the size of the components, however short times are preferred for efficient productivity. Therefore the duration of the HIP-step, once said pressure and temperature has been reached, is in the range of 1-4 hours. After the HIP process has been completed, said solid body may preferably be subjected to any suitable heat treatment, such as annealing. After HIP, the solid bodies are separated by cutting the capsule. The capsule may be removed from the individual solid bodies, for example by pickling. The capsule may also remain on the individual solid bodies and instead be removed during machining. Figure 8 shows the solid body after HIP.

In the final step of the method, the solid body resulting from the HIP process is subjected to a metal machining operation in which at least a portion of lateral wall 4 is removed and the exposed cladding material 8 is machined to a cladding 60 of a predetermined thickness. Typically the machining operation is performed by turning in a lathe.

Figure 7 shows schematically a metal machining apparatus 30 in the form of a lathe 30. The lathe comprises a head stock 31 to which a face driver 32 is connected. The face driver 32 is rotated by the drive unit of the lathe (not shown) and engages the solid body 20 to rotate

it during milling. To engage the solid body, the face driver 32 is provided with hardened drive pins 33 which bite into the end surface 3a of the solid body 20 so that the rotational movement of the face driver is transferred to the solid body 20. In the center of the face driver a male center 34 in the form of a truncated cone is located. The male center of the lathe is adopted to engage the female centering means 11 of the solid body. Hence, a center in the metal machining apparatus is designed so that it may engage a centering means in the solid body and vice versa.

The tailstock 35 of the lathe comprises a female center 36 which consists of a tapered sleeve 37 with an inner shape in the form of a truncated cone. The sleeve is adopted to receive the male centering means 12 in the top wall 9 of the solid body 20. The center further comprises a shaft (not shown) by which it is attached to the tail stock of the lathe. In this case the center is a live center which is rotatable arranged in the tailstock. However, it could also be a so called dead center. A metal cutting tool 38, i.e. a lathe tool or lathe steel is provided to remove metal from the solid body.

In operation the male center 34 of the face drive is inserted into the female centering means 11 in the first end surface 3a of the solid body and the female center 37 of the tailstock of the lathe receives the male centering means 12 in the second end surface 4a of the solid body 20. The face driver presses the solid body towards the female center in the tailstock of the lathe and simultaneously the drive pins 33 are forced into the end surface 3a of the solid body. The solid body is centered in the lathe when both the male and female centers of the lathe are in engagement with the male and female centering means of the solid body.

If necessary, the centering means 11, 12 in the solid body 20 may be exposed prior to centering the solid body in the lathe. For example, by removing a portion of the capsule by grinding with a hand held tool.

After centering of the solid body, turning is performed until a cladding of desired thickness is achieved. This is achieved in that the control system of the lathe is programmed with a pre-determined distance between the center of the pre-manufactured body and the lathe tool. During turning at least a portion of lateral wall is 4 is removed by the lathe cutting tool

38. Typically the entire lateral wall is removed. The exposed cladding material is then also removed by the lathe tool until the pre-determined distance is reached and a cladding of a predetermined thickness is obtained.

The injection nozzle blank may thereafter be subjected to further machining into a final injection nozzle, for example drilling of holes and further machining of the cladding.

EXAMPLE

The invention will in the following be described with reference to a comparative example.

Six injection nozzles blanks were manufactured according to the inventive method. The injection nozzles comprised a hollow body of the steel AISI H13/SS2242 filled with a cladding material of NiCr22MoNbTi in powder form. The nozzles blanks had the following dimensions, see figure 19: Height (H) 62.7 mm, base diameter (BD): 32.5 mm, upper diameter (UD): 21.5 mm.

The pre-manufactured bodies that were used in the manufacturing of the nozzle blanks were provided with a male centering means in the form of a truncated cone in the top and female centering means also in the form of a truncated cone in the bottom. The male centering means had a base diameter of 11 mm, a height of 5.5 mm and an inclination angle of 60°.

The six pre-manufactured bodies were placed in a capsule and HIP:ed for 1 hour at a pressure of 970 bar and a temperature of 1150°C. Subsequently the solid bodies were machined in a lathe of the type Okuma Space Turn LB3000EX. The lathe was provided with centers in face driver and tail stock which corresponded to the centering means in the top and bottom walls of the solid bodies.

After turning the nozzles were cut at a position of 14-16 mm from the top and the cut surfaces were investigated in a light microscope to determine the thickness of the cladding layer. The dashed line in figure 9 shows the position for the cut. Four measurements were made around the cut surface and the maximum and minimum readings were recorded.

As comparison, six further nozzles were manufactured and subjected to measurement as described above. However, the pre-manufactured bodies for these nozzles were not provided with centering means. The comparative nozzles were also turned in a lathe as described above but were clamped by a chuck in one end of the solid body.

5 The results from the measurements are shown in table 1:

Sample	Comparative Nozzles			Sample	Inventive Nozzles		
	Max	Min	Difference		Max	Min	Difference
1	3.26	2.66	0.60	1	3.07	2.95	0.12
2	3.13	2.82	0.31	2	3.00	2.94	0.06
3	3.12	2.80	0.32	3	3.04	2.92	0.12
4	3.13	2.78	0.35	4	2.98	2.93	0.05
5	3.45	2.50	0.95	5	2.98	2.95	0.03
6	3.05	2.89	0.16	6	3.01	2.92	0.09

Table: Cladding thickness of test nozzles

The results show that, in comparison with the conventionally manufactured nozzles, a much narrower tolerance of the thickness of the cladding is achieved in the nozzles manufactured by the inventive method. The targeted cladding thickness of the inventive nozzles is 3 mm and the measured variation in thickness around the core is in the range of 0.03 – 0.12 mm. In comparison the comparative nozzles have cladding thickness which varies in the range of 0.16 – 0.95 mm around the core.

CLAIMS

1. A method for manufacturing a metallic body (50) having a core (5) and metallic cladding (60), comprising the following steps:

- 5 - providing at least one a hollow body (2) that comprises a bottom wall (3), a core (5) that extends from the bottom wall (3) and a lateral wall (4) that extends from said bottom wall (3) and encloses the core (5) so that an inner space (6) is formed around the core (5);
- filling the inner space (6) with a metallic cladding material (8);
- closing the inner space (6) by arranging a top wall (9) on the lateral wall (4);
- positioning the filled hollow body (2) in a capsule (10) and evacuating air from the
10 capsule (10) and sealing the capsule (10);
- subjecting the capsule (10) to Hot Isostatic Pressing (HIP) at a predetermined temperature, a predetermined pressure and for a predetermined time so that the cladding material (8) is bonded to the hollow body (2) and a solid body (20) is formed.
- machining the solid body (20) in a metal machining apparatus (30) wherein at least a
15 portion of the lateral wall (4) is removed and the exposed cladding material (8) is machined to a cladding (60) of a predetermined thickness;

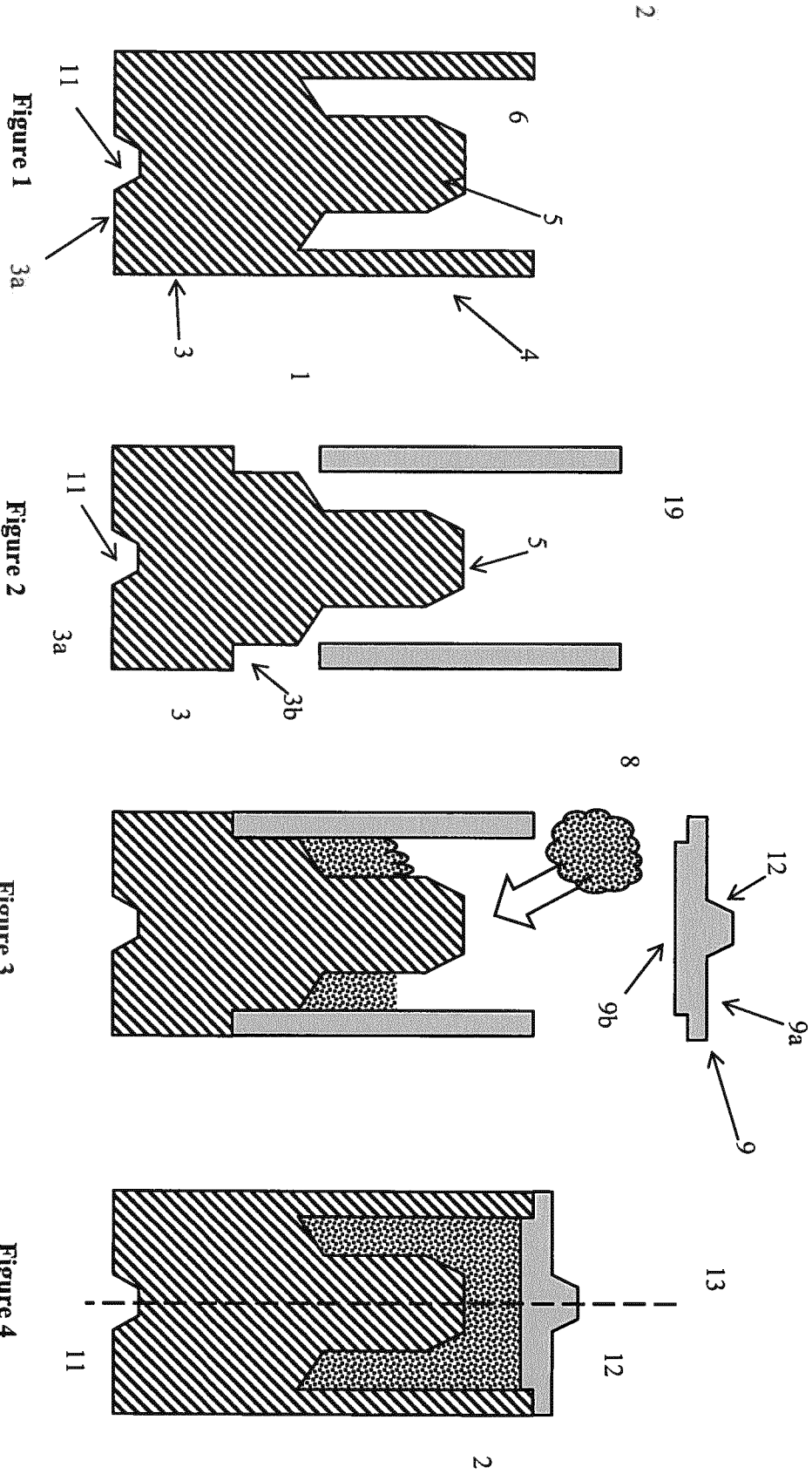
characterized in that

- 20 - the bottom wall (3) and the top wall (9) of the hollow body (2), prior to the step of Hot Isostatic Pressing, each are provided with at least one centering means (11, 12) for centering the final body (20) obtained in the step of Hot Isostatic Pressing in the metal machining apparatus (30).

2. The method according to claim 1, wherein the final body (20) is centered in the metal machining apparatus (30) by engagement between the centering means (11, 12) in the final body (20) and corresponding centers (34, 37) in the metal machining apparatus (30).

3. The method according to claim 1 or 2, wherein the centering means (11, 12) is a male centering means (12) or a female centering means (11).
4. The method according to any of claims 1 - 3, wherein the male centering means (12) is a cone or a truncated cone.
- 5 5. The method according to any of claims 1 – 3, wherein the female centering means (11) is a recess having the shape of a cone or a recess having the shape of a truncated cone.
6. The method according to any of claims 1 – 5, wherein the centering means (11, 12), prior to Hot Isostatic Pressing, are provided in the center of the bottom wall (3) and the center of the top wall (9) of the hollow body (2) and are aligned along a perpendicular axis (13)
10 which extends through the center of the core (5) of the hollow body (2) and both centering means (11, 12).
7. The method according to any of claims 1 – 6, comprising the step of arranging at least a first cover piece (40) in the capsule (10), wherein the cover piece (40) comprises a protrusion (40c) which is adopted to be fully received in a female centering means (11) or
15 wherein the cover piece 40 comprises a recess (40d) which is adopted to fully receive a male centering means (12).
8. The method according to any of claims 1 – 7, wherein the hollow body (2) is formed by a metal machining operation in which metal is removed from a solid blank (1).
9. The method according to any of claims 1 – 7, wherein the hollow body (2) is
20 manufactured by attaching a tube section (19) to a pre-body (1) comprising a bottom wall (3) from which a core (5) extends such that the tube section (19) forms the lateral wall (4) around the core (5).
10. The method according to any of claims 1 – 9, comprising the step of manufacturing a plurality of hollow bodies (2) and placing the hollow bodies (2) on top of each other in the
25 capsule (10).

11. The method according to claim 10, wherein the bottom wall (3) of each hollow body (2) comprises a female centering means (11) and wherein the top wall (9) of each hollow body (2) comprises a male centering means (12), wherein the female and male centering means are adopted such that a male centering means can be fully received in a female centering means.
- 5
12. The method according to claim 11, wherein the bottom wall (3) and/or the top wall (9) of the plurality of hollow bodies (2) are provided with a coating (21) that prevents bonding of adjacent hollow bodies (2).
13. The method according to claims 11 or 12, comprising the step of placing a first cover piece (40) in the capsule (10) and then positioning the hollow bodies (2) on top of each other in the capsule, wherein the cover element (40) has a first surface (40a) which is directed towards the bottom of the capsule (10) and a second surface (40b) which comprises a protrusion (40c) which is adopted to be fully received in a female centering means (11).
- 10
14. The method according to any of claims 1 – 13, wherein the metal machining apparatus (30) is a lathe.
- 15



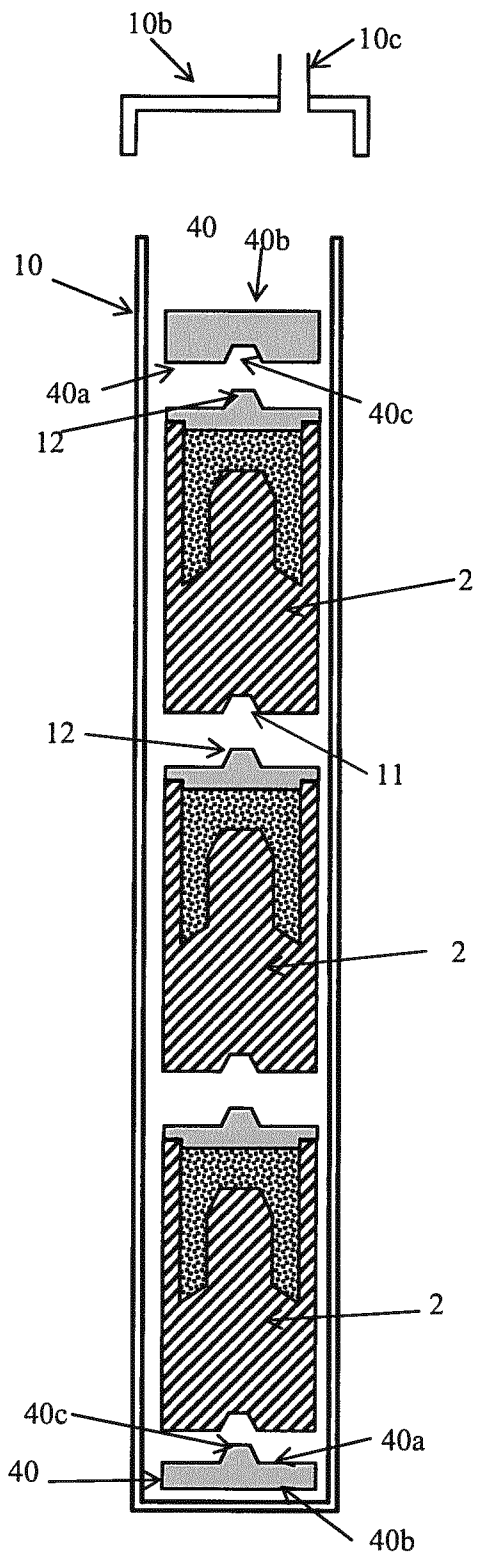


Figure 5

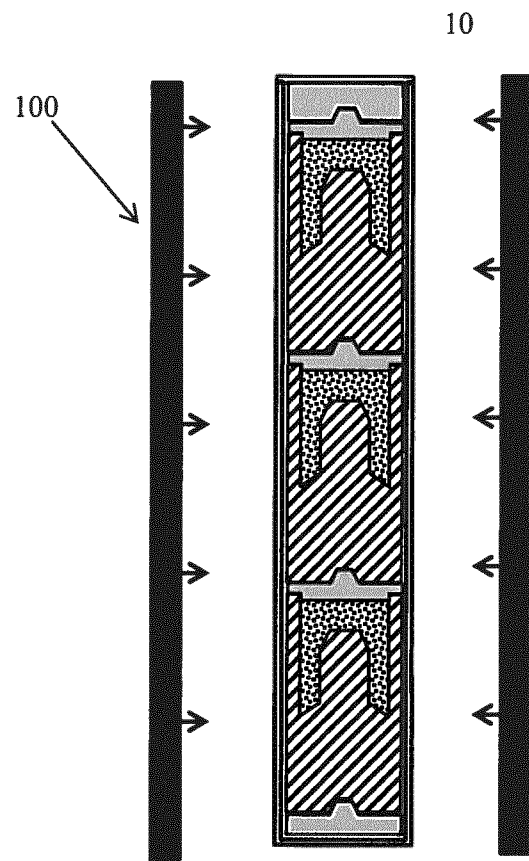


Figure 6

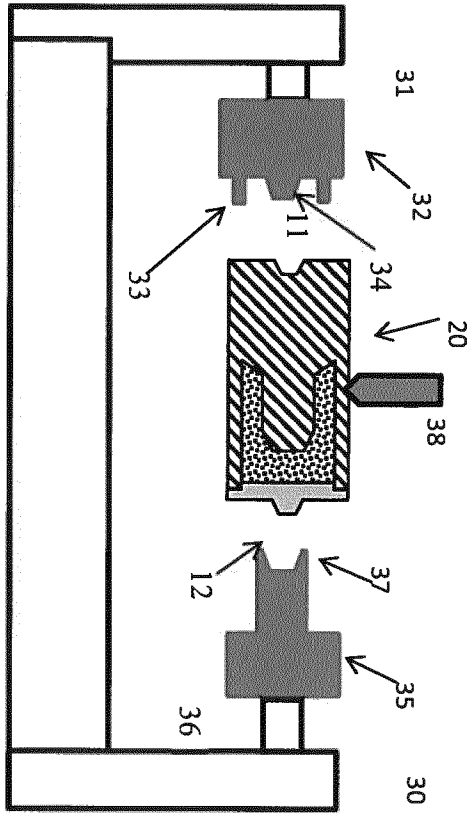


Figure 7

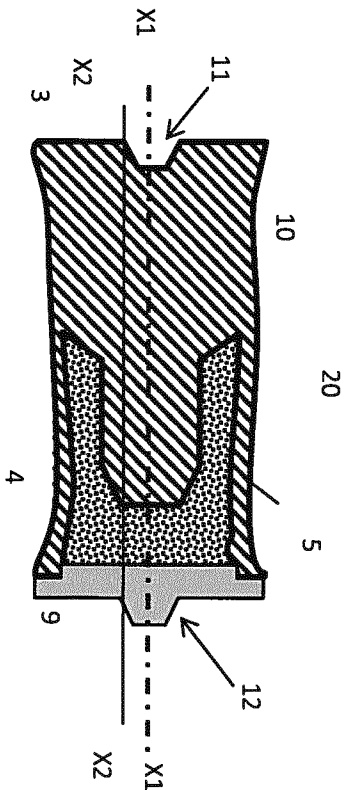


Figure 8

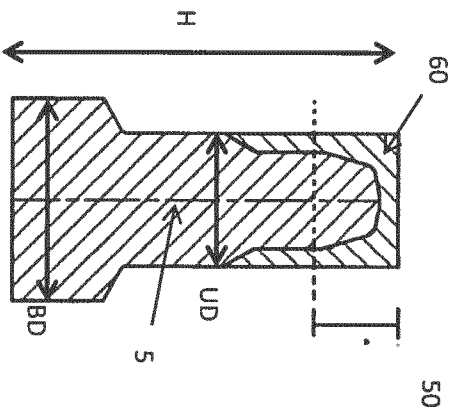


Figure 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/075109

A. CLASSIFICATION OF SUBJECT MATTER
 INV. B22F3/15 B22F7/08 B22F7/06
 ADD.

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)
 B22F B21B B21D F02M

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 004 653 A (KROISENBRUNNER WALTER [AT]) 2 April 1991 (1991-04-02)	1-7,14
Y	abstract figure 2 column 1, line 7 - line 19 column 2, line 3 - line 28 column 2, line 44 - column 3, line 29 claims 1,16-18	8-13
Y	----- WO 2004/030850 A1 (MAN B & W DIESEL AS [DK]; HOEG HARRO ANDREAS [DK]) 15 April 2004 (2004-04-15) cited in the application page 1, line 1 - line 10 page 5, line 10 - page 6, line 34 page 13, line 34 - page 15, line 15 page 16, line 12 - line 30 claims 1-10; figures -----	8-13

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search 18 February 2015	Date of mailing of the international search report 25/02/2015
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Ceulemans, Judy
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/075109

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