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(11) EP 0 773 351 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
14.05.1997 Bulletin 1997/20

(51) Int. Cl.⁶: F01L 3/22

(21) Application number: 96114721.2

(22) Date of filing: 13.09.1996

(84) Designated Contracting States:
DE FR GB

(30) Priority: 14.09.1995 JP 237264/95

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(54) Method for producing a cylinder head unit having valve seats and a valve seat member

(57) A method is provided for producing a cylinder head unit of an internal combustion engine. Said cylinder head unit comprising a cylinder head body, an air intake system communicating with a combustion chamber at an at least one intake port opening, an exhaust system communicating with the combustion chamber at an at least one exhaust port opening. The intake and exhaust port openings are each operable by respective intake and exhaust valves guided by respective valve guides accommodated in respective valve guide holes, whereby a valve seat made of a material different from that of the cylinder head body is bonded to each of the respective intake and exhaust port openings. Each valve seat is provided by metallurgically bonding a respective valve seat member onto a valve seat seating surface of the respective intake and exhaust port openings. An annular projection consisting of two surfaces and projecting from the inner circumferential side of the valve seat seating surface of the respective opening is formed. Further, the valve seat member has an outer circumferential surface sloping towards its center and a bottom surface continuing from the outer circumferential surface and sloping with a smaller gradient than that of the outer circumferential surface towards the center of said openings. Said bottom surface is in line-contact with said projection when said valve seat member is set onto said respective valve seat seating surface.

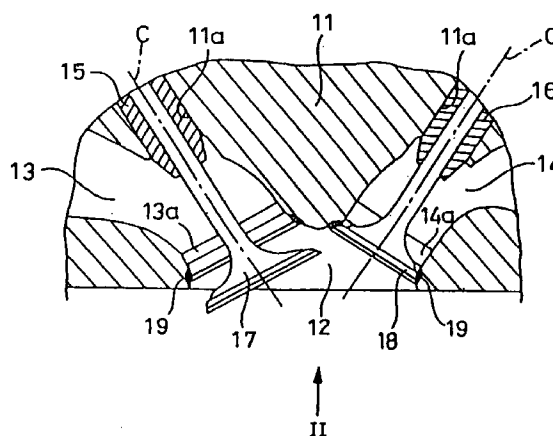


FIGURE 1

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Description

This invention relates to a method for producing a cylinder head unit of an internal combustion engine, said cylinder head unit comprising a cylinder head body, an air intake system communicating with a combustion chamber at an at least one intake port opening, an exhaust system communicating with the combustion chamber at an at least one exhaust port opening, said intake and exhaust port openings are each operable by respective intake and exhaust valves guided by respective valve guides accommodated in respective valve guide holes, whereby a valve seat made of a material different from that of the cylinder head body is bonded to each of the respective intake and exhaust port openings, and to a valve seat member for a valve seat of an internal combustion engine having a cylinder head unit comprising a cylinder head body, an air intake system communicating with a combustion chamber at an at least one intake port opening, an exhaust system communicating with the combustion chamber at an at least one exhaust port opening, said intake and exhaust port openings are each operable by respective intake and exhaust valves guided by respective valve guides accommodated in respective valve guide holes.

In recent years, engines for vehicles such as motor vehicles have become generally of the four cycle, four valve, overhead camshaft (OHC) type and the engine cylinder is constituted with a cylinder block and a cylinder head made of aluminum alloy. The combustion chamber is formed between the cylinder head and a piston reciprocating within the cylinder block. The cylinder head is constituted with a cylinder head body (made of aluminum alloy) and formed with intake and exhaust ports connected to the combustion chamber and valve seats attached to the combustion chamber side openings of those ports. The valve seats are attached to parts contacted with the valve faces of the intake and exhaust valves. The valve seats are made of iron-based sintered alloy excellent in wear resistance and high temperature strength because the valve seats are repeatedly contacted with the intake and exhaust valves and subjected to high temperatures.

As a method of attaching the valve seats to the cylinder head body, press fit has been conventionally employed. The press fit method, however, has potential problems; difference in thermal conductivity between different metals and minute gaps present between them decrease thermal conductivity when heat is transmitted to the cylinder head, abnormal combustion occurs as a result of insufficient cooling of the cylinder head body, and valves are overheated. To solve such problems associated with the press fit, a laser cladding method has been proposed (for example a Japanese laid-open patent publication No. 62-150014) in which metallic powder of the valve seat material which is excellent in heat resistance, wear resistance, and corrosion resistance is melted with laser beam and deposited (cladded) to part of the cylinder head body where the valve seat is to be attached, and the cladded layer is machined to form the valve seat.

The laser cladding method, however, has also drawbacks; the material on the cylinder head body side is also melted when the metallic powder of the valve seat material is melted and material defects are produced such as blow holes due to gas produced, shrinkage pores due to solidification, loss of strength improving treatment applied to the cylinder head, decrease in bond strength, and deformation.

In order to solve the problems associated with the valve seat bonding method described above, the inventors have considered a technique in which a valve seat member made of iron-based sintered alloy is bonded under heat and pressure. With this method, the cylinder head body of aluminum alloy is heated by electric current application to cause plastic flow while the valve seat member is heated, pressed and sunk into the cylinder head body. At that time, atoms on the boundary surface between both components diffuse mutually and both components are firmly bonded together without gaps.

FIG. 16 shows the method with an enlarged cross section of part of a cylinder head body (1) and a valve seat member (2). The valve seat member (2) is set to a valve seat seating surface (3) as shown with broken lines. After the valve seat member (2) is sunk in the cylinder head body (1), excess portion is ground and finished. FIG. 16 also shows the predetermined sinking depth range of the valve seat member (2). With this method, the valve seat member (2) and the cylinder head body (1) little melt. As a result, no material defects are produced, thermal conductivity is retained favorably, and a cylinder head free from thermal influence is obtained.

However, even the method described above has the following problems to be solved. First, the amount of sinking the valve seat member (2) into the cylinder head body (1) varies and when the amount exceeds a preset range, problems occur. That is to say, as shown in FIG. 17(a), when the sinking amount of the valve seat member (2) is small, the valve seat member (2) might separate because the press contact surface is small and the bond strength is low. When the sinking amount of the valve seat member (2) is too great as shown in FIG. 17(b), material in the portion (G) is lost, a gap is produced between the valve seat and the valve face, and the valve function is impaired. When the valve seat member (2) is set as shown in FIGs. 18(a), 18(b), and 18(c) in surface contact (in line contact as seen in cross section) with the valve seat seating surface (3) with different relative positions due to machining errors, the contact surface area varies. It will be easily appreciated that the variation in the contact surface area causes variation in the amount of heat generated by electric resistance during press contact, which in turn causes variation in the sinking amount.

The portion of the valve seat seating surface (3) in the vicinity of which the valve seat member (2) is set, tends to melt easily because of the increased electric current density caused by the dominant electric current at the time of electric current application to the cylinder head body (1). The valve seat member (2) shown in FIG. 19(a) has an outer cir-

cumferential surface (2a) sloping down toward its center and a bottom surface (2b) continuing from the outer circumferential surface (2a) and sloping with a milder gradient than that of the outer circumferential surface. As shown in FIG. 19(a), when the outer circumferential surface (2a) of the valve seat member (2) is set close to the cylinder head body (1), then the nearby portion H tends to melt easily. Therefore, after the valve seat member (2) is sunk and machined by grinding, the nearby portion remains as a melt layer in the interface between the valve seat and the cylinder head body (1), whereby the valve seat separation is apt to happen.

Accordingly, it is an objective of the present invention to provide a method as indicated above which enhances the bonding strength for the valve seat members and simultaneously eliminates the possibility of valve seat separation.

It is a further objective of the present invention to provide a valve seat member as indicated above which facilitates a decrease in bonding strength.

According to the present invention, this objective is solved for a method in that said respective valve seat is provided by metallurgically bonding a respective valve seat member onto a valve seat seating surface of the respective intake and exhaust port openings, whereby an annular projection consisting of two surfaces and projecting from the inner circumferential side of the valve seat seating surface of the respective opening is formed, and the valve seat member has an outer circumferential surface sloping towards its center and a bottom surface continuing from the outer circumferential surface and sloping with a smaller gradient than that of the outer circumferential surface towards the center of said openings, whereby said bottom surface is in line-contact with said projection when said valve seat member is set onto said respective valve seat seating surface.

According to the present invention, this objective is solved for a valve seat member in that said valve seat member consisting of a metal or a metal alloy being capable of forming an eutectic alloy with that cylinder head unit and comprising an outer circumferential surface sloping towards its center and a bottom surface continuing from the outer circumferential surface and sloping with a smaller gradient than that of the outer circumferential surface in a direction away from said outer circumferential surface, whereby said bottom surface is configured such that it is capable to come into line-contact with a projection projecting from the inner circumferential side of a valve seat seating surface of the respective intake or exhaust port opening of the cylinder head unit.

According to a preferred embodiment of the present invention, said valve seat surface comprises a flat plane transverse to the axis of the respective opening, first and second inside tapered surfaces continuing to the respective opening and an outside tapered surface continuing to the combustion chamber.

In that case, it is advantageous when flat plane and the first inside tapered surface form the annular projection which has an apex with an obtuse angle.

According to an advantageous embodiment of the present invention, the cross-section of said annular valve seat member is defined by the outer circumferential surface, the bottom surface, an inner circumferential surface and a top surface.

Whereby, it is possible that the inner circumferential surface is formed by a slant surface approximately parallel to the outside tapered surface of the valve seat seating surface, and an axial surface extending axially from the inner circumferential side edge of said slant surface, and that the top surface connects the outer circumferential surface and the slant surface and being approximately parallel to the flat plane of the valve seat seating surface.

In order to enhance further the bonding strength, it is advantageous when the pressing force and/or the electricity are applied according to a predetermined pattern. Therefore, the pattern for the pressing force may comprise the first pushing force being applied at an early stage of the bonding process and then a second pushing force being applied with a certain higher value till bonding is completed.

Thereby, it is advantageous when the pattern of the applied electricity or current starts after a time has lapsed after the application of the first pushing force, whereby a first electric current is applied for a first time period followed by a first rest period with decreasing electric current, next a second electric current is applied for a second time period followed by a second rest period with decreasing electric current and finally a third electric current is applied for a third time period.

Other preferred embodiments of the present invention are laid down in further dependent claims.

In the following, the present invention is explained in greater detail with respect to several embodiments thereof in conjunction with the accompanying drawings, wherein:

FIG. 1 is a sectional side view showing a valve seat of an embodiment of the invention;

FIG. 2 is a view taken in the direction of the arrow II in FIG. 1;

FIG. 3 is a sectional side view of the valve seat member being set against the valve seat seating surface;

FIG. 4 is a sectional side view of the valve seat member to be sunk in the valve seat seating surface;

FIG. 5 is a plan view of a pressure device for use in bonding the valve seats to the port openings of the cylinder head;

FIG. 6 is a side view of a pressure device for use in bonding the valve seats to the port openings of the cylinder head;

FIG. 7 is a sectional side view of the valve seat member being brought into contact with the electrode;

FIG. 8 is a diagram showing the patterns of electric current and pushing force;

FIG. 9 is a sectional side view of the alloy layer being generated between the metallic material of the film of the valve seat member and the metallic material of the cylinder head body;

FIG. 10 is a sectional side view of the metallic material of the cylinder head developing the plastic flow;

FIG. 11 is a sectional side view of the valve seat member sunk in the cylinder head body;

FIG. 12 is a sectional side view of the valve seat finished by machining;

FIG. 13 is a diagram showing an example of the relation between the length of the projected line and surface pressure;

FIG. 14 is a diagram showing an example of the relation between the thickness of the valve seat and the bending deformation factor;

FIG. 15 is a diagram showing an example of the relation between the angle of the outer circumferential surface and the probability of separation;

FIG. 16 is a sectional side view illustrating a conventional method for bonding the valve seat member to the cylinder head body;

FIG. 17: (a) is a sectional side view showing a bonding defect in which the sinking amount of the valve seat member is inadequate, and (b) showing another bonding defect in which the sinking amount of the valve seat member is excessive;

FIG. 18(a), (b) and (c) are views each showing a respective state of the valve seat member being in surface-contact with the cylinder head body; and

FIG. 19: (a) is a sectional side view showing the valve seat being set with its outer circumferential surface positioned closer to the cylinder head body than its bottom surface, and (b) showing the valve seat member to be sunk in the valve seat seating surface.

FIG. 1 is a partial sectional view of a cylinder head according to the invention, FIG. 2 is a view taken in the direction of the arrow II of FIG. 1, and FIG. 3 is a sectional view showing a valve seat member being set on a valve seat seating surface, depicting only a part of the cylinder head body and the valve seat member on an enlarged scale. In these figures, numeral (11) designates a cylinder head body of a four-stroke, four-valve OHC type engine. The cylinder head body (11) is made by casting with Al alloy. The cylinder head body (11) is formed with a recess (12), facing downward, for defining a combustion chamber, together with a piston (not shown) reciprocating in a cylinder block, and on either side of the recess (12) is formed with two intake ports (13) and two exhaust ports (14), both ports having openings at the recess (12). By the way, the cylinder head body 11 is shown with the bottom (the surface at which the recess 12 is open) upward in FIG. 3.

The Al alloy, the material of the cylinder head body (11), is Al-Si-Mg-based A1 alloy specified as AC4C, AC4B or AC2B in JIS standard. The reason why this material is adopted is that the valve seat can be bonded more firmly in this material than in any other Al alloy. As shown in FIG. 1, in the upper wall portions of the intake and exhaust ports (13), (14) are mounted intake and exhaust valves (17), (18) through valve guides (15), (16), respectively. At openings (13a), (14a) of the ports (13), (14) are formed valve seat seating surfaces (40), to which are bonded valve seats (19) described later. The valve guides (15), (16) are press-fit in valve guide holes (11a) formed in the cylinder head body (11). The valve guide holes (11a) are formed, with their axes C coinciding with the axes of the openings (13a), (14a). By the way, numeral 8 in FIG. 2 designates a plug mounting hole.

The valve seat (19) shown in FIG. 1 is a seat in which an annular valve seat member (20) is bonded under heat and pressure to the valve seat seating surface (40) and finished by machining. As shown in FIG. 3, the valve seat seating surface (40) consists of a flat plane (41) perpendicular to the axis of the opening (13a) or (14a), first and second inside tapered surfaces (42), (43) continuing to the port (13) or (14), and an outside tapered surface (44) continuing to the recess 12. Two surfaces, the flat plane (41) and the first inside tapered surface (42), forms an annular projection (46) projecting on the inner circumferential side of the opening (13a) or (14a) and having an apex of an obtuse angle.

The valve seat member (20), as shown in FIG. 3, consists of an annular body (21) made of Fe-based sintered alloy covered with a Cu film (22). As for the material of the annular body (21) of this embodiment, the alloy infiltrated with Cu is adopted for the purpose of avoiding development of internal resistance heat during energization as described later. The film (22) is formed by electroplating the annular body (21) so as to be 0.1-30 μm in thickness.

The valve seat member (20) is of an annular shape as a whole, but its axial cross section is defined by an outer circumferential surface (50), a bottom surface (51), an inner circumferential surface 52, and a top surface (53). The outer circumferential surface (50), as shown in FIG. 3, slopes down toward the center of the valve seat member, and the bottom surface (51) continues from the outer circumferential surface (50) and slopes with a milder gradient than that of the outer circumferential surface (50). The inner circumferential surface (52) is formed by a slant surface (52a) approximately parallel with an outside tapered surface (44) of the valve seat seating surface (40), and an axial surface (52b) extending axially from the inner circumferential side edge of the slant surface (52a). The top surface (53) connects the outer circumferential surface (50) and the slant surface (52a), and is formed so as to be approximately parallel with the flat plane (41) of the valve seat seating surface (40).

When the valve seat member (20) is set against the valve seat seating surface (40) as shown in FIG. 3, the bottom surface (51) comes into contact with the apex (45) of the annular projection, and the larger diameter side end portion projects into the recess (12); further, the angle α between the outside tapered surface (44) of the valve seat seating surface (40) and the outer circumferential surface (50), and the angle β between the first inside tapered surface (42) of the valve seat seating surface (40) and the bottom surface (51), are set so as to satisfy the relation $\alpha \cong \beta$.

A pressure device (24) shown in FIG. 5 to FIG. 7 is used for bonding the valve seat members (20) to the valve seat seating surfaces (40) of the cylinder head body 11. This pressure device (24) has a lower platen (26) fixed to the lower portion of a base frame (25), and an upper platen (27) is disposed upwardly of the lower platen (26) for vertical movement so as to be able to come into contact with the lower platen (26). The upper platen (27) is fixed to the lower end of a rod (28a) which is the end portion of a cylinder device (28) mounted to the upper portion of the base frame vertically.

The upper and lower platens (26), (27) are supplied with electricity from a power supply (not shown) through conductors (26a), (27a). The conductor (27a) connected to the upper platen (27) is adapted to be bent or moved vertically in response to the vertical movement of the upper platen (27). In this embodiment, the upper platen acts as an anode and the lower platen as a cathode. On the upper portion of the base frame supporting said cylinder device (28) is mounted a laser displacement meter (30) for measuring displacement of the upper platen (27) from the distance between the upper platen (27) and a reflection member (29) fixed to the front portion of the upper platen (27), using a laser beam being reflected by the reflection member (29).

To bond the valve seat member (20), first is fixed on the lower platen (26) an upper electrode (31), on which is mounted fixedly the cylinder head body (11). At this time, the cylinder head body (11) is positioned, with the recess (12) side upward and with the axis of the port opening, on which the valve seat member (20) is bonded, coinciding with the axis of a rod (28a) of the cylinder device (28).

Then, as shown in FIG. 7, a guide rod (32) is inserted from the recess (12) side into the valve guide hole (11a) of the port on which the valve seat member (20) is bonded. The guide rod (32) is made of a metallic rod (32a) covered with insulating material such as alumina, and has a length such that it protrudes from the end face of the cylinder head body (11) on the combustion chamber side when inserted into the valve guide hole (11a) and held in place by a stopper (32c). The insulating member (32b) is formed, in this embodiment, using a method in which ceramic material such as alumina is flame sprayed and then finished by polishing.

In turn, on the port opening is placed the valve seat member (20), on which is laid an upper electrode (33). The upper electrode (33) is formed with a through hole (33a) for receiving said guide rod (32) at the axial center of its cylindrical metallic body, and at the lower end portion is formed with a tapered surface (33b) adapted to be in close contact with the slant surface (52a) (FIG.3) of the valve seat member (20) as well as a circumferential surface (33c) for positioning adapted to be in close contact with the axial surface (52b) over its entire circumference. On the lower end portion of this upper electrode (33) is fixed a magnetic body (33d) for magnetically attracting the valve seat member (20).

That is, when the guide rod (32) is inserted into the through hole (33a), the upper electrode (33) is positioned coaxially with the axis of the port opening of the cylinder head body (11), and when the tapered surface (33b) and the circumferential surface (33c) are brought into close contact with the valve seat member (20), the valve seat member (20) is also positioned coaxially with the port opening.

In this way, after laying the upper electrode (33) on the valve seat member (20), the upper electrode (33) is turned so as to receive a check whether the valve seat member (20) is fitted reliably. Then, the cylinder device (28) is operated and the upper platen (27) is moved downward so as to be brought into close contact with the upper electrode (33). At this time, the bottom surface of the upper platen (27) and the top surface of the upper electrode (33) are adapted to be parallel to each other. Then, said cylinder device (28) is operated again to move the upper platen (27) downward, and the valve seat member (20) is pressed against the cylinder head body (11) with a certain pushing force. Since the movement of the upper electrode (33) is restricted by the guide rod (32), the direction of the pushing force exerted on the valve seat member (20) coincides with the axis of the opening (13a) or (14a). Therefore, the valve seat member (20) is pressed coaxially with the opening (13a) or (14a).

The pushing force is changed according to the pushing force pattern shown in solid line in FIG. 8. That is, a first pushing force P1 of a certain lower value is applied at the early stage of the bonding process and then a second pushing force P2 of a certain higher value is applied till the downward movement is completed.

When the upper platen (27) becomes stable after application of the first pushing force P1, the distance between the laser displacement meter (30) and the reflection member (29) is measured by the displacement meter and recorded as a sinking movement starting point of the upper platen (27). When a certain time has elapsed after application of the first pushing force P1, a voltage is applied between said upper and lower platens (27), (26) so as to allow an electric current to flow through the upper electrode (33), valve seat member (20), cylinder head body (11), and lower electrode (31). The current flows from the upper electrode (33) toward the cylinder head body (11), and the current value is changed according to the current pattern shown in dash line in FIG. 8.

The applied current pattern is as follows: the first electric current I1 for a period t1, then a rest period r1, next the second electric current I2 larger than the first current I1 for a period t2, a rest period r2 again, finally the third current I3 larger than the second current I2 for a period t3, and while the second pushing force P2 is applied at the final stage of

bonding, the electric current value is reduced to 0. That is, the current value is increased stepwise. Pressure conversion from the first pushing force P1 to the second pushing force P2 is performed during the time the second electric current I2 is applied and when a time t4 has elapsed after the electric current value was changed to the second current I2. In addition, the applied electric current value (electric current density) is changable between the intake and exhaust port sides in such a manner that the current density on the exhaust port (14) side is larger (for example, by a factor of 1.1) than that on the intake port (13) side. A specific example for the electric current values, period, and pushing force in FIG. 8 is given below.

a. Electric current value

Intake port side: I1 = 64kA, I2 = 68kA, I3 = 72kA

Exhaust port side: I1 = 70kA, I2 = 75kA, I3 = 80kA

(all values $\pm$ 4kA)

b. Period (both for intake and exhaust port sides)

t1, t2, t3 = 0.1sec (6/60 sec)

t4 = 0.05sec (3/60sec)

r1, r2 = 1/60sec

c. Pushing force (both for intake and exhaust port sides)

P1 = 12kN

P2 = 24kN

At this time, as shown in FIG. 3, the bottom surface (51) of the valve seat member (20) is in line-contact with the apex (45) of the annular projection of the cylinder head body (11) and the contact area between these two components is very small, so that when the electric current is applied, electric resistance becomes large enough to develop heat at the contact portion. The resistance heat will be transmitted over the entire contact surface between the valve seat member (20) and the cylinder head body (11). When the temperature of the interface between the valve seat member (20) and the cylinder head body (11) rises as described above, atoms in the material metals (Cu in the film (22) and Al alloy in the cylinder head body (11)) pressed against each other in solid phase, start moving actively and diffusing mutually between two materials.

As a result of mutual atom diffusion described above, the crystalline structure near the interface turns to eutectic alloy between Cu in the film (22) and Al alloy in the cylinder head body (11), that is, into the state capable of changing from solid phase to liquid phase at lower temperature than pure Cu or Al alloy of the cylinder head body (11) does. The state near the interface at this time is shown schematically in FIG. 9. The portion where said eutectic alloy layer is produced as a result of the mutual atom diffusion, is designated by symbol A.

When the temperature near the interface rises higher and a part of the eutectic alloy layer turns into liquid phase, the atom diffusion phenomena become more active and the interface between solid phase and liquid phase will expand together with the growth of the eutectic alloy layer. While liquidization of the eutectic alloy layer proceeds, the Al alloy of the cylinder head body (11) adjacent to the eutectic alloy layer develops plastic flow (plastic deformation) because of the valve seat member (20) being pressed and its own temperature rise due to the resistance heat. Since the plastic flow develops approximately symmetrically in the vertical direction in FIG. 9 with the internal contact portion as a center, the liquidized eutectic alloy is removed from the contact portion to the outside in association with the plastic flow. FIG. 10 shows the removed portion of the eutectic alloy in symbol B. At this time, a part of the film (22) of the valve seat member (20) is turned into eutectic alloy and removed from the contact portion, therefore a part of the annular body (21) comes into contact with the Al alloy, which brings about the atom diffusion phenomena between these materials. The portion developing atom diffusion is shown in symbol C in FIG. 10.

A part of the eutectic alloy layer being removed from the contact portion and the Al alloy developing the plastic flow, cause the valve seat member (20) to sink into the cylinder head body (11). After the valve seat member (20) has begun sinking, the pushing force is increased to the value of said second pushing force P2. The increased pushing force causes the increase in the plastic flow rate in the Al alloy, thereby increasing the volume of the eutectic ally removed. As a result, new eutectic alloy consisting of Cu-Al alloy is produced in a contact portion where no reaction has occurred so far, the phenomena described above is repeated, and these eutectic alloy layers are liquidized to be removed. In the

course of this process, the area where mutual atom diffusion occurs, will expand in the interface between Fe-base sintered alloy, the material of the annular body (21), and Al alloy.

Not only during the time the current is flowing, but after the current is shut off, the reaction proceeds till the temperature falls to the point where the reaction is impossible to occur;

the phenomena of generation of the eutectic alloy layer → liquidization → removal associated with plastic flow,

and the phenomena of mutual atom diffusion between Fe-based sintered alloy and Al alloy, occur simultaneously while the valve seat member (20) continues to sink; almost all the outer circumferential surface is sunk into the cylinder head (11) as shown in FIG. 11.

When the amount of sinking has almost stopped to increase, pushing operation by the cylinder device (28) is stopped, the final position of the upper platen (27) is determined, using the laser displacement meter (30), from the distance between the displacement meter and the reflection member (29), then the upper platen (27) is moved upward, and the cylinder head body (11) is dismounted from the pressure device (24). The mean current value and the total energization periods are calculated by the time all the procedure is completed. Next, height difference between the sinking movement starting point and the final point is calculated to determine the total amount of sinking of the valve seat member (20). If this value does not fall in the range of a predetermined allowable value, the bonding process is regarded as defective. In this embodiment, this allowable value is set to be 0.5-2.5mm. Usually, the allowable value of about 1mm-1.5mm is preferable, depending on the material of the cylinder head body (11).

In the finishing process, an unnecessary portion is removed from the cylinder head body (11) bonded with the valve seat member (20), for example, by grinding as shown in FIG. 12. The finishing process removes the unnecessary portion of the annular body (21) together with the film (22), and the valve seat (19) bonded to the cylinder head body (11) through the atom diffusion area shown in symbol C in FIG. 11, is obtained. The valve seat (19) now takes the form such that the dimensions A (length determining the projected area), B (maximum thickness), and θ (angle between the outer circumferential surface and the machined surface) in FIG. 12 will satisfy the relations $A \geq 2\text{mm}$, $B \geq 0.9\text{mm}$, and $\theta \geq 30^\circ$.

① The valve seat (19) and the cylinder head body (11) are bonded firmly without clearance as a result of atom diffusion. Therefore, heat resistance between two components becomes small, thereby improving the cooling function of the cylinder head. Further, the cylinder head body (11) does not melt in the manufacturing process as described above, material defects such as blow holes and shrinkage pores due to solidification will not be produced.

② The valve seat member (20), when set against the valve seat seating surface (40), is in line-contact, at the bottom surface (51), with the apex (45) of the annular projection (46) as shown in FIG. 3. That is, the valve seat member (20) is not in surface-contact with the valve seat seating surface (40). If in surface-contact, the valve seat member (20) will vary in its sinking amount owing to the machining tolerance. However, the valve seat member (20) is in the state of line-contact in this embodiment and the contact area between the valve seat member and the cylinder head body is always constant, so that the amount of heat development becomes constant and the variation of the sinking amount is controlled within a preset range. As a result, predetermined thickness is maintained, adequate bond strength can be achieved without possibility of separation, and desirable valve functions can be fulfilled without difficulties such as lack of base material.

③ The valve seat member (20), as shown in FIG. 3, is set against the valve seat seating surface (40) such that the angle α between the outer circumferential surface (50) and the outside tapered surface (44), and the angle β between the bottom surface (51) and the first inner tapered surface (42) satisfies the relation $\alpha \geq \beta$. As a result, with regard to the valve seat member (20), the bottom surface (51) is positioned closer to the cylinder head body (11) than the outer circumferential surface (50). Therefore, as shown in FIG. 4, the electric current does not concentrate on the outer circumferential surface (50) side, but flows from the bottom surface (51) side rather dominantly to the cylinder head body (11). Thus, with regard to the cylinder head body (11), the electric current density becomes high at the portion facing the bottom surface (51), which increases the possibility of melting. However, the melt layer is removed outside the interface without any residual owing to the valve seat member (20) being pressed. As a result, the separation of the valve seat (19) due to the material defects will not happen.

④ The valve seat (19) which is finished after the valve seat member (20) has been sunk into the cylinder head body, takes the form satisfying the relations $A \geq 2\text{mm}$, $B \geq 0.9\text{mm}$, and $\theta \geq 30^\circ$ as shown in FIG. 12. For the valve seat (19) to avoid its subsidence or its damage due to the combustion pressure or the seating impact of the valve face, it is important that the area of the interface between the cylinder head body (11) and the valve seat member, and accordingly the surface pressure exerted on the cylinder head body (11), is kept within a certain value and the stiffness of the valve seat itself is kept at a certain value or more. Experiments have found that the length A of the

projected line is preferably $A \geq 2\text{mm}$ because the surface pressure exceeds the tolerable value when the projected line length A is smaller than 2mm , as shown in FIG. 13. Also, the bending deformation factor assumes a large value for the thickness B thinner than 0.9mm , but does not exceed that value when the thickness is 0.9mm or more, as shown in FIG. 14. Therefore, the thickness B is preferably $B \geq 0.9\text{mm}$. Further, as shown in FIG. 15, unless the angle θ between the outer circumferential surface (50) and the machined surface is kept at least at 30° , that is, as much cross sectional area is maintained, the probability of the valve seat separation is increased. Therefore, $\theta \geq 30^\circ$ is preferable.

⑤ At the time of bonding the valve seat member (20), the electric current density on the exhaust port (14) side is larger than that on the intake port (13) side. The valve seat (19) on the exhaust port side is subject to hot exhaust gas at all times and kept in a condition of higher temperature than the valve seat (19) on the intake port side so that it is desirable that the projected line length (projected area) is secured larger on the exhaust port (14) side than on the intake port (13) side. As shown in FIG. 2, the electric current density on the exhaust port (14) side is set larger than that on the intake port (13) side so that the projected line length of the valve seat (19) on the exhaust port (14) side is secured large enough to prevent the subsidence or deformation of the valve seat. On the intake port (13), an adequate opening (13a) area can be secured without sacrificing the distance between the valve seats (13).

⑥ When the valve seat member (20) is bonded, excellent bonding can be achieved by adopting the energization and pushing force patterns shown in FIG. 8. That is, the electric current is increased gradually in three steps with two rest periods r_1 , r_2 interposed therebetween so that temperature at the interface does not rise excessively, preventing the cylinder head body (11) from melting into a liquid phase. If an excessive electric current is kept flowing without rest periods, the temperature of the annular body (21) of the valve seat member (20) exceeds the phase transformation point of steel as a result of a temperature rise due to resistance heat of the steel itself, and will develop the martensite transformation in the cooling process. In that case, the annular body (21) increases its hardness and turns to a material of poor tenacity, losing the adequate functions as a valve seat. As for the pushing force, at the beginning the first pushing force P_1 of a relatively small magnitude is applied to avoid abrupt impact to the valve seat member (20), and then is increased to the second pushing force P_2 during the time the second electric current I_2 is applied, whereby excellent bonding is achieved.

B. Modified embodiments

This invention is not limited to the foregoing embodiment, but various modifications can be made as follows:

- ① Materials of the cylinder head body (11) and the valve seat member (20) are not restricted to those in the foregoing embodiment, but any material that will produce eutectic alloy between two components may be used.
- ② This invention can be applied not only to automobile engines but any other type of engines such as motorcycle engines also.

According to the invention described above, the valve seat member is set against the valve seat seating surface of the cylinder head body in line-contact relation. Therefore, when the valve seat member is bonded to the cylinder head body under heat and pressure, the amount of heat development becomes constant and the variation of the sinking amount is controlled within a specified range so that the thickness is always maintained at a preset value and adequate bond strength can be obtained without the possibility of separation.

The electric current does not concentrate on the outer circumferential side of the valve seat at the time of bonding, and the magnitude of the electric current flowing from the bottom surface side to the cylinder head body is increased. Therefore, the electric current density becomes high at the portion facing the bottom surface, which increases the possibility of melting; the melt layer is removed outside the interface without any residual owing to the valve seat member being pressed so that the valve seat separation due to the material defects will not happen.

Claims

1. Method for producing a cylinder head unit of an internal combustion engine, said cylinder head unit comprising a cylinder head body (11), an air intake system communicating with a combustion chamber (12) at an at least one intake port opening (13a), an exhaust system communicating with the combustion chamber (12) at an at least one exhaust port opening (14a), said intake and exhaust port openings (13a, 14a) are each operable by respective intake and exhaust valves (17, 18) guided by respective valve guides (15, 16) accommodated in respective valve guide holes (11a), whereby a valve seat (19) made of a material different from that of the cylinder head body (11) is bonded to each of the respective intake and exhaust port openings (13a, 14a), **characterized in that** said respective valve seat (19) is provided by metallurgically bonding a respective valve seat member (20) onto a valve

seat seating surface (40) of the respective intake and exhaust port openings (13a, 14a), whereby an annular projection (46) consisting of two surfaces (41, 42) and projecting from the inner circumferential side of the valve seat seating surface (40) of the respective opening (13a, 14a) is formed, and the valve seat member (20) has an outer circumferential surface (50) sloping towards its center and a bottom surface (51) continuing from the outer circumferential surface (50) and sloping with a smaller gradient than that of the outer circumferential surface (50) towards the center of said openings (13a, 14a), whereby said bottom surface (51) is in line-contact with said projection (46) when said valve seat member (20) is set onto said respective valve seat seating surface (40).

2. Method according to claim 1, **characterized in that** said valve seat surface (40) comprising a flat plane (41) transverse to the axis of the respective opening (13a, 14a), first and second inside tapered surfaces (42, 43) continuing to the respective opening (13a, 14a) and an outside tapered surface (44) continuing to the combustion chamber (12).

3. Method according to claim 2, **characterized in that** the flat plane (41) and the first inside tapered surface (42) form the annular projection (46) having an apex (45) with an obtuse angle.

4. Method according to at least one of the preceding claims 1 to 3, **characterized in that** the cross-section of said annular valve seat member (20) is defined by the outer circumferential surface (50), the bottom surface (51), an inner circumferential surface (52) and a top surface (53).

5. Method according to claim 4, **characterized in that** the inner circumferential surface (52) is formed by a slant surface (52a) approximately parallel to the outside tapered surface (44) of the valve seat seating surface (40), and an axial surface (52b) extending axially from the inner circumferential side edge of said slant surface (52a), and that the top surface (53) connects the outer circumferential surface (50) and the slant surface (52a) and being approximately parallel to the flat plane (41) of the valve seat seating surface (40).

6. Method according to at least one of the preceding claims 2 to 5, **characterized in that** a first angle (α) between the outside tapered surface (44) of the valve seat seating surface (40) and the outer circumferential surface (50), and a second angle (β) between the first inside tapered surface (42) of the valve seat seating surface (40) and the bottom surface (51) are set to satisfy the relation:

$$\alpha \geq \beta.$$

7. Method according to at least one of the preceding claims 1 to 6, **characterized in that** said metallurgical bonding of said valve seat blanks (20) comprises:

(a) placing the valve seat member (20) onto the valve seat seating surface (40) of said openings (13a, 14a) of said cylinder head unit (11), and

(b) pushing an electrode (33) against the end face of said valve seat member (20) opposite to said cylinder head unit (11) with a pushing direction matched with an axis (C) of said intake or exhaust valve (17, 18), whereby said electrode (33) being adapted to apply electricity to said cylinder head unit (11) through said valve seat member (20).

8. Method according to claim 7, **characterized by** advancing a guide rod (32) coaxially aligned with said electrode (33) such that said guide rod (32) enters said valve guide hole (11a) and simultaneously guides said electrode for matching the pushing direction with the axis (C) of said valve (17, 18), whereby said guide rod (32) is fixed to or separated from said electrode (33).

9. Method according to at least one of the preceding claims 1 to 8, **characterized in that** the pressing force and/or said electricity are applied according to a predetermined pattern.

10. Method according to at least one of the preceding claims 7 to 9, **characterized in that** during step (a) said electrode (33) magnetically attracts said valve seat member (20) for placing said valve seat member (20) on the valve seat seating surface.

11. Method according to at least one of the preceding claims 7 to 10, **characterized in that** after steps (a) and/or (b) the electrode (33) is rotated for checking whether the valve seat member (20) is fitted correctly.

12. Method according to claim 9 or 10, **characterized in that** the pattern for the pressing force comprising a first pushing force (P1) being applied at an early stage of the bonding process and then a second pushing force (P2) being applied with a certain higher value till bonding is completed.

13. Method according to at least one of the preceding claims 9 to 12, **characterized in that** the pattern of the applied electricity or current starts after a time has lapsed after the application of the first pushing force (P1), whereby a first electric current (I1) is applied for a first time period (t1) followed by a first rest period (r1) with decreasing electric current, next a second electric current (I2) is applied for a second time period (t2) followed by a second rest period (r2) with decreasing electric current and finally a third electric current (I3) is applied for a third time period (t3).

14. Method according to claim 13, **characterized in that** the values of the first through third electric currents (I1, I2, I3) fulfill the following relation:

$$I1 < I2 < I3.$$

15. Method according to claim 13 or 14, **characterized in that** the second pushing force (P2) starts during the second time period (t2), the second electric current (I2) is applied after a fourth time period (t4) has lapsed after the electric current value has been changed to the second electric current (I2), whereby while the second pushing force (P2) is applied at the final stage of bonding the electric current value is reduced to 0.

16. Method according to at least one of the preceding claims 13 to 15, **characterized in that** the first through fourth time periods have the following values:

$$t1 = t2 = t3 = 0.1 \text{ sec (6/60 sec), and}$$

$$t4 = 0.05 \text{ sec (3/60 sec)}$$

whereby the pushing forces have the following values:

$$P1 = 12\text{kN and } P2 = 24\text{kN}.$$

17. Method according to at least one of the preceding claims 1 to 16, **characterized in that** the values of the electric current is changeable between the intake and exhaust port openings such that the values of the electric current applied to the exhaust port opening are larger than the values of the electric current applied to the intake port openings.

18. Method according to claim 17, **characterized in that** the values of the applied electric current are as follows:

intake port opening: I1=64kA, I2=68kA, I3=72kA, and

exhaust port opening: I1=70kA, I2=75kA, I3=80kA,

whereby all values may have a deviation of $\pm 4\text{kA}$.

19. Method according to at least one of the preceding claims 1 to 18, **characterized in that** said valve seat member (20) is made of an Fe-based sinter alloy being provided with a coating (22) of a metal or metal alloy being capable of forming an eutectic alloy with that cylinder head unit (11).

20. Method according to at least one of the preceding claims 1 to 19, **characterized in that** the material of said cylinder head unit (11) is selected out of the group consisting of AC4C, AC4B and AC2B as set forth in the Japanese Industrial Standard (JIS).

21. Method according to at least one of the preceding claims 1 to 20, **characterized in that** the magnitude of sinking of the valve seat base material (20) into the opening (13a, 14a) is measured continuously during the whole bonding process.

22. Method according to claim 21, **characterized in that** said magnitude of sinking of the valve seat base material (20) into the opening (13a, 14a) is controlled, in particular on the basis of said measured sinking value.

23. Method according to at least one of the preceding claims 1 to 22, **characterized in that** after the bonding process a finishing process is applied such that a length (A) determining the projected area, a maximum thickness (B) and an angle (θ) between the outer circumferential surface and the machined surface of said valve seat (19) satisfy the relations:

$$A \geq 2\text{mm}, B \geq 0.9\text{mm and } \theta \geq 30^\circ.$$

24. A valve seat member (20) for a valve seat (19) of an internal combustion engine having a cylinder head unit comprising a cylinder head body (11), an air intake system communicating with a combustion chamber (12) at an at least one intake port opening (13a), an exhaust system communicating with the combustion chamber (12) at an at least one exhaust port opening (14a), said intake and exhaust port openings (13a, 14a) are each operable by respective intake and exhaust valves (17, 18) guided by respective valve guides (15, 16) accommodated in respective valve guide holes (11a), **characterized in that** said valve seat member (20) consisting of a metal or a metal alloy being capable of forming an eutectic alloy with that cylinder head unit (11) and comprising an outer circumferential surface (50) sloping towards its center and a bottom surface (51) continuing from the outer circumferential surface (50) and sloping with a smaller gradient than that of the outer circumferential surface (50) in a direction away from said outer circumferential surface (50), whereby said bottom surface (51) is configured such that it is capable to come into line-contact with a projection (46) projecting from the inner circumferential side of a valve seat seating surface (40) of the respective intake or exhaust port opening (13a, 14a) of the cylinder head unit (11).

25. A valve seat member according to claim 24, **characterized in that** the cross-section of said annular valve seat member (20) is defined by the outer circumferential surface (50), the bottom surface (51), an inner circumferential surface (52) and a top surface (53).

26. A valve seat member according to claim 25, **characterized in that** the inner circumferential surface (52) is formed by a slant surface (52a) and an axial surface (52b) extending axially from the inner circumferential side edge of said slant surface (52a), and that the top surface (53) connects the outer circumferential surface (50) and the slant surface (52a).

27. A valve seat member according to at least one of the preceding claims 24 to 26, **characterized in that** said valve seat member (20) is made of an Fe-based sinter alloy being provided with a coating (22) of a metal or metal alloy being capable of forming an eutectic alloy with that cylinder head unit (11).

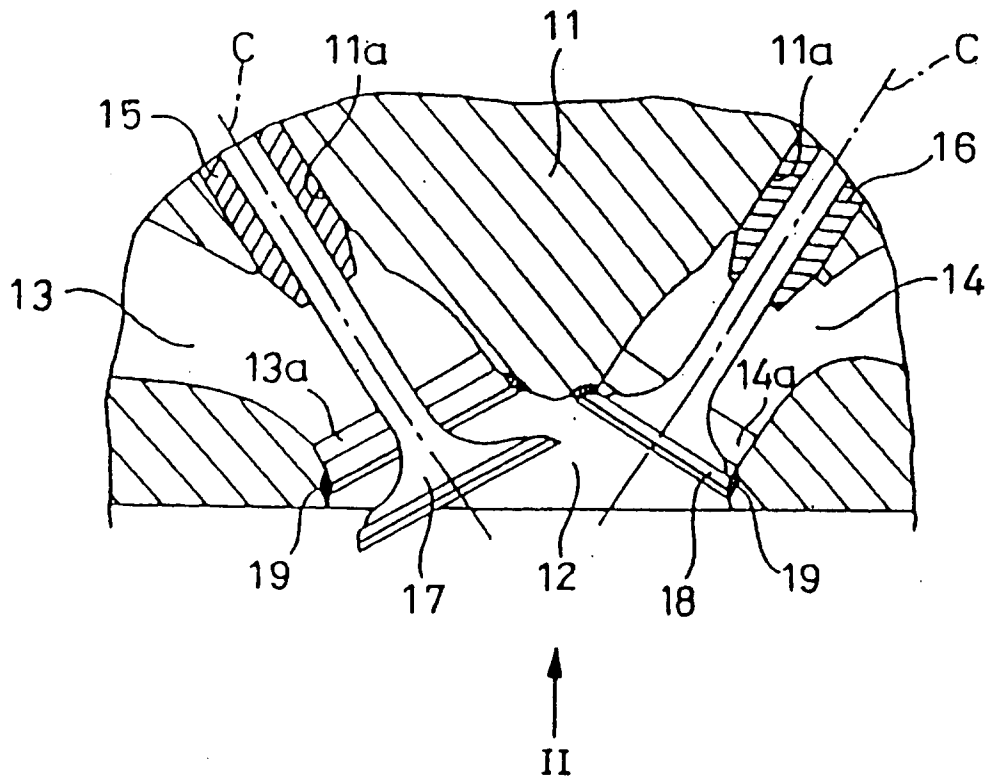


FIGURE 1

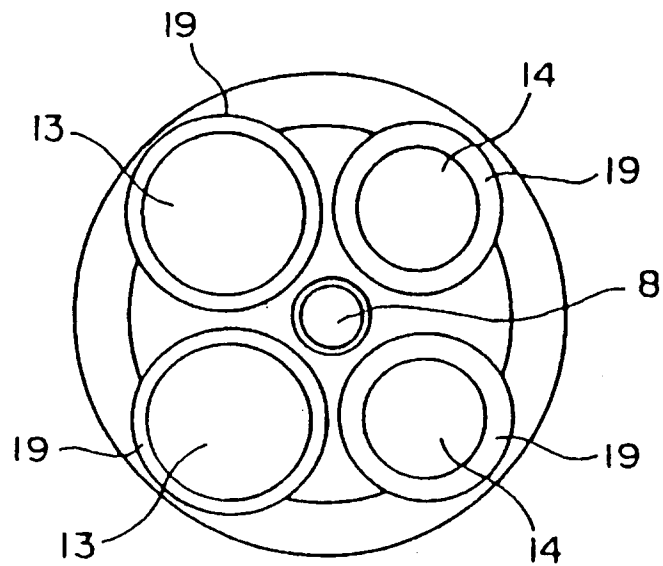


FIGURE 2

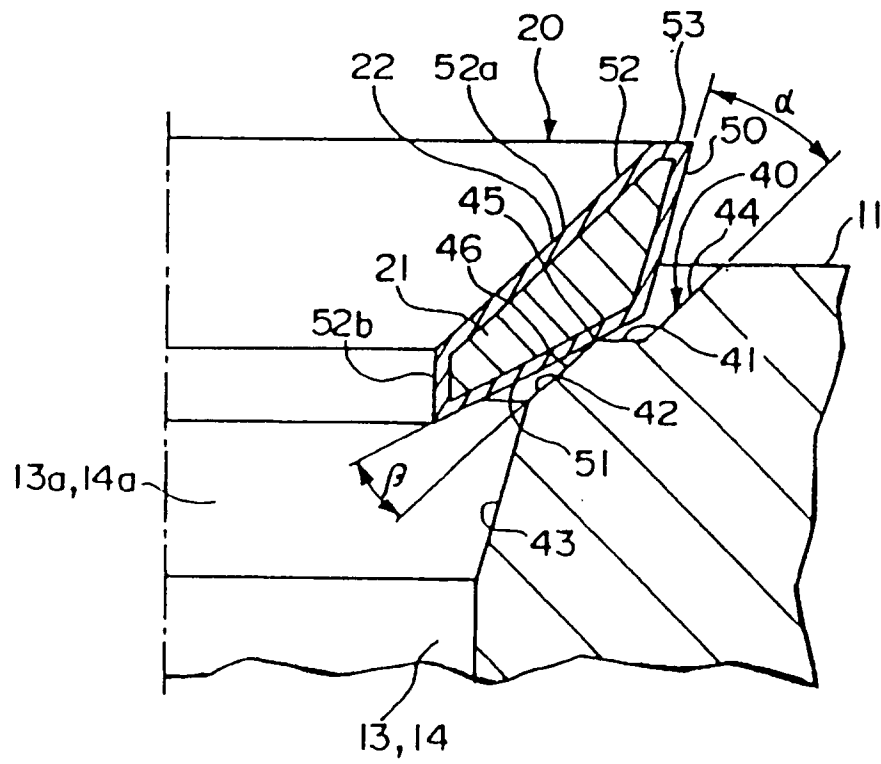


FIGURE 3

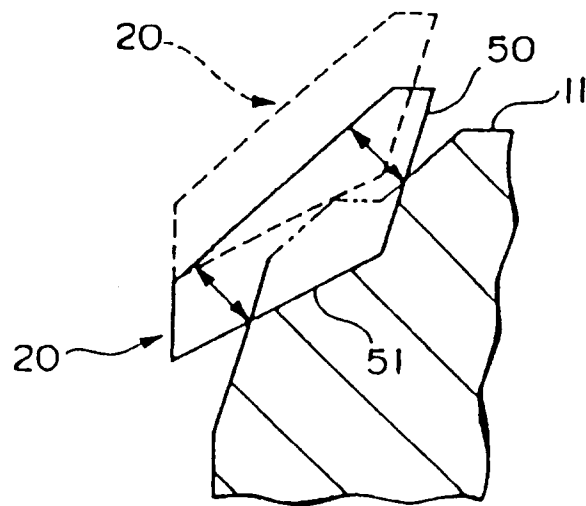


FIGURE 4

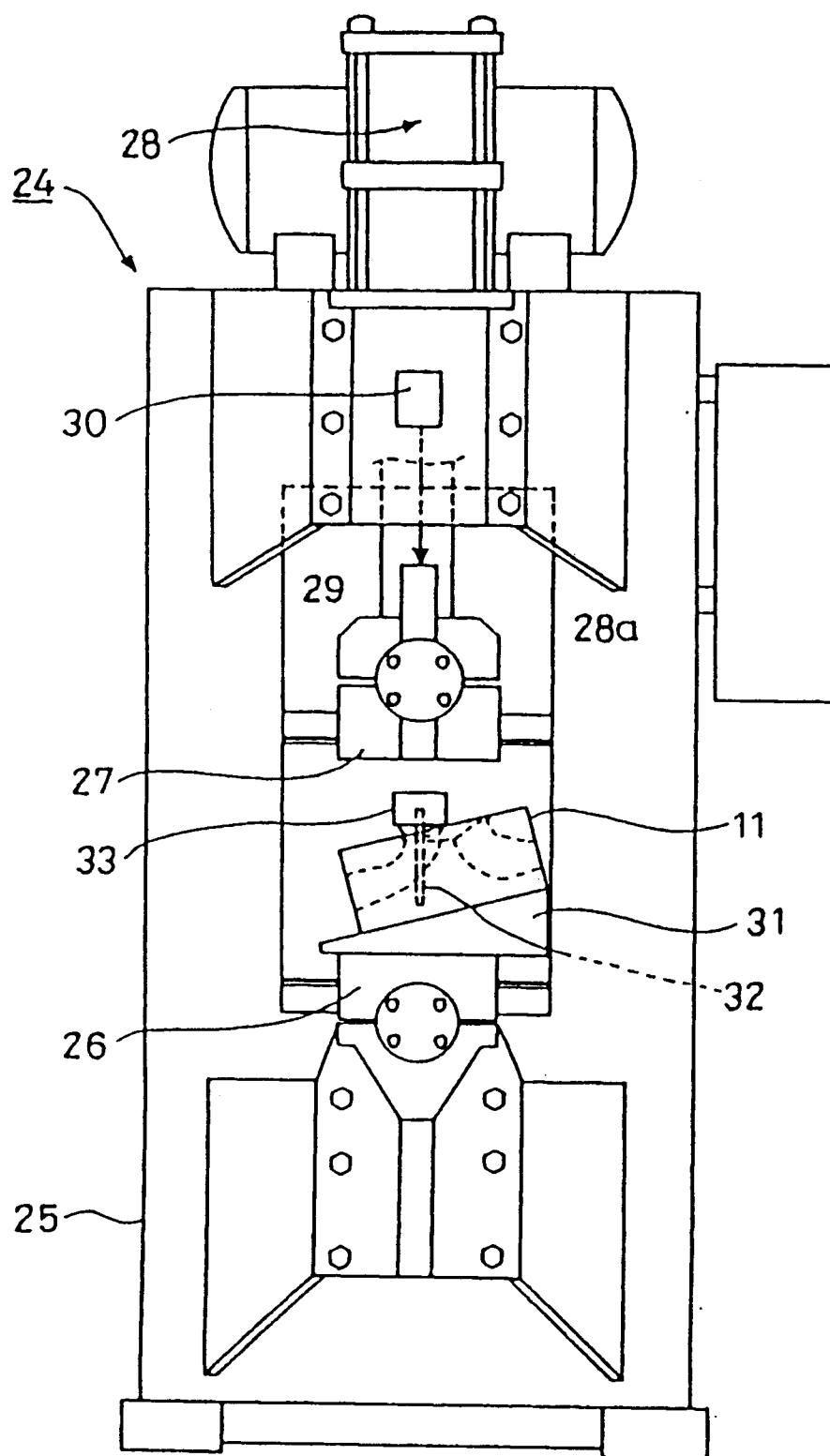


FIGURE 5

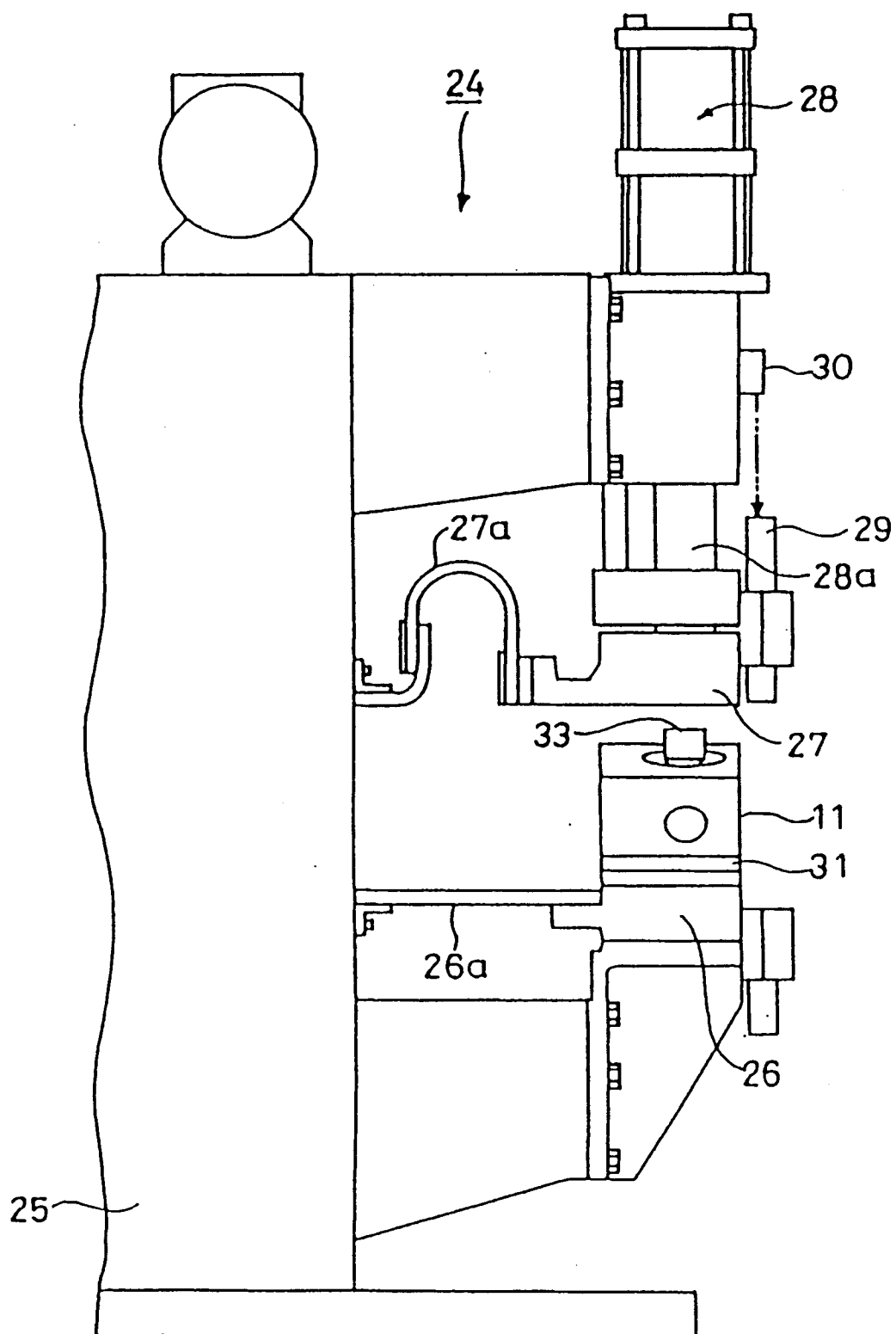


FIGURE 6

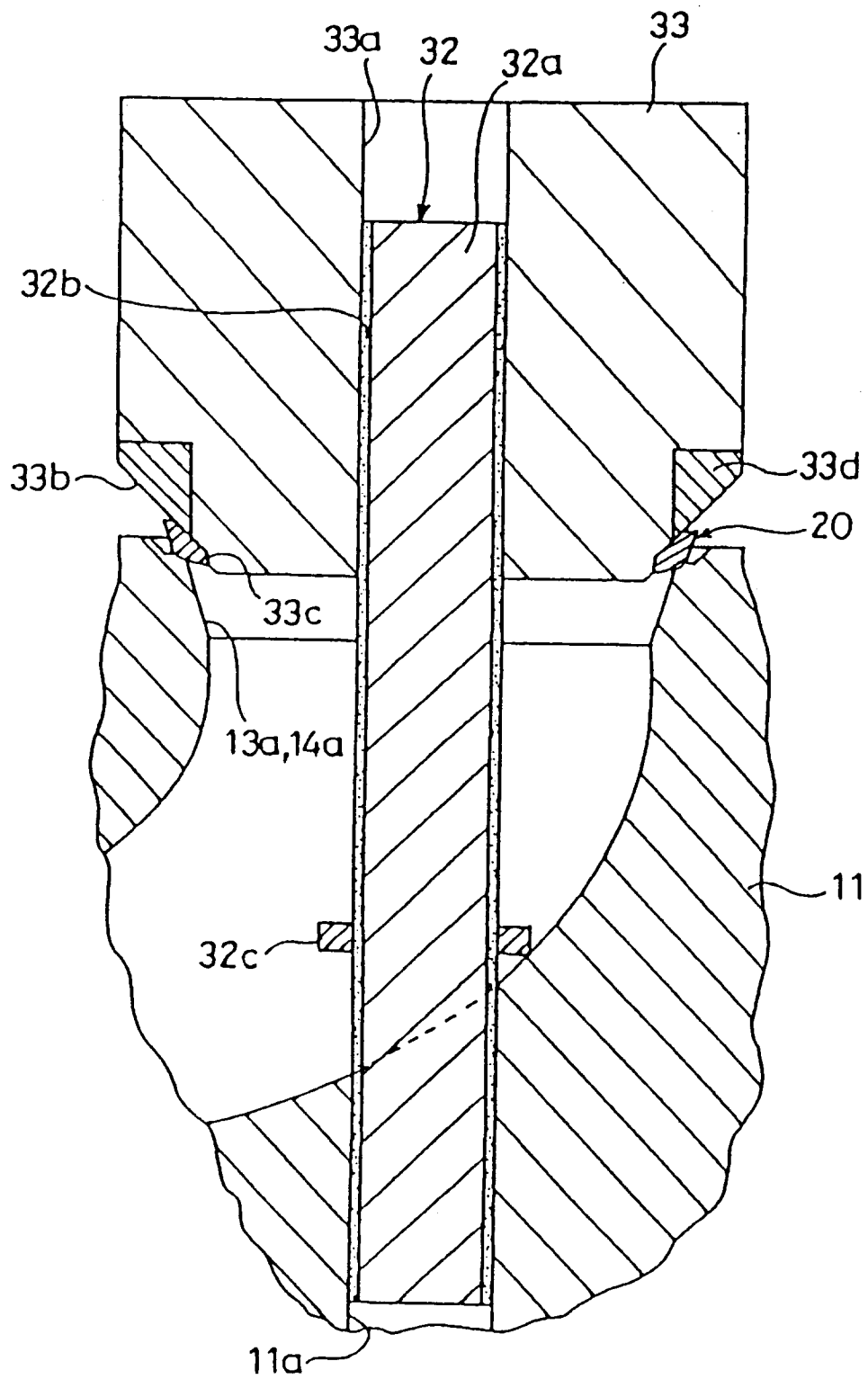


FIGURE 7

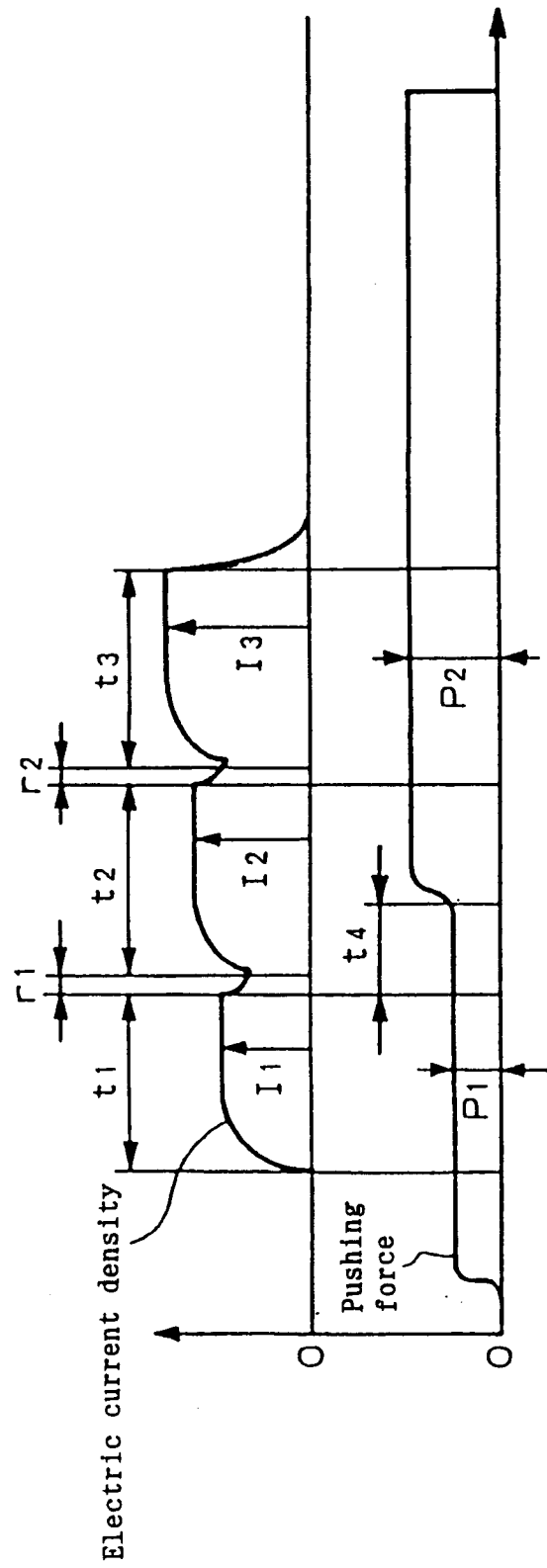


FIGURE 8

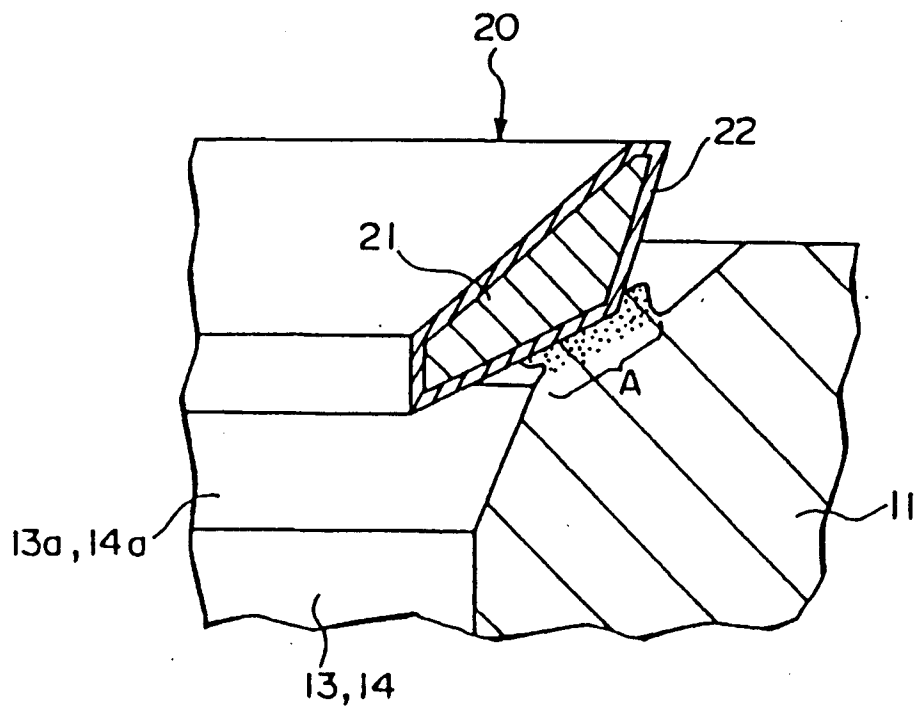


FIGURE 9

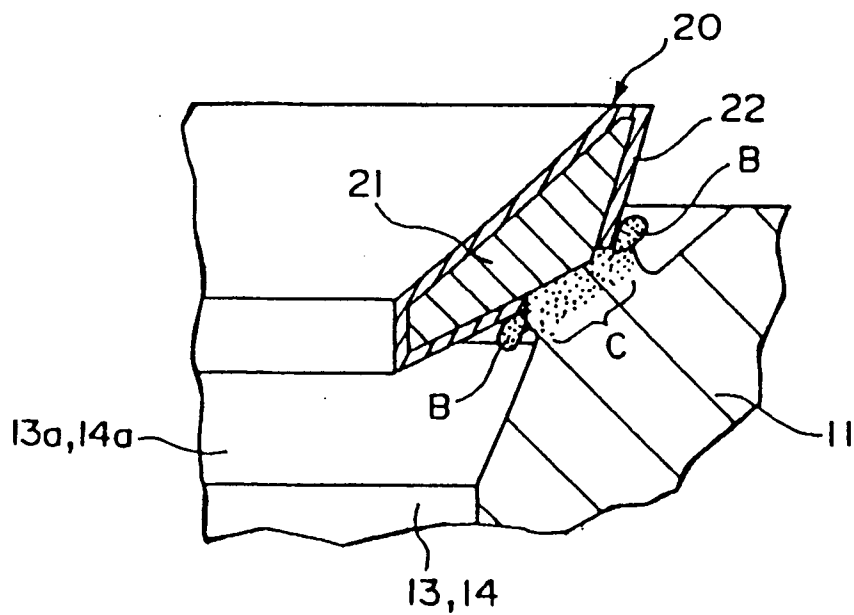


FIGURE 10

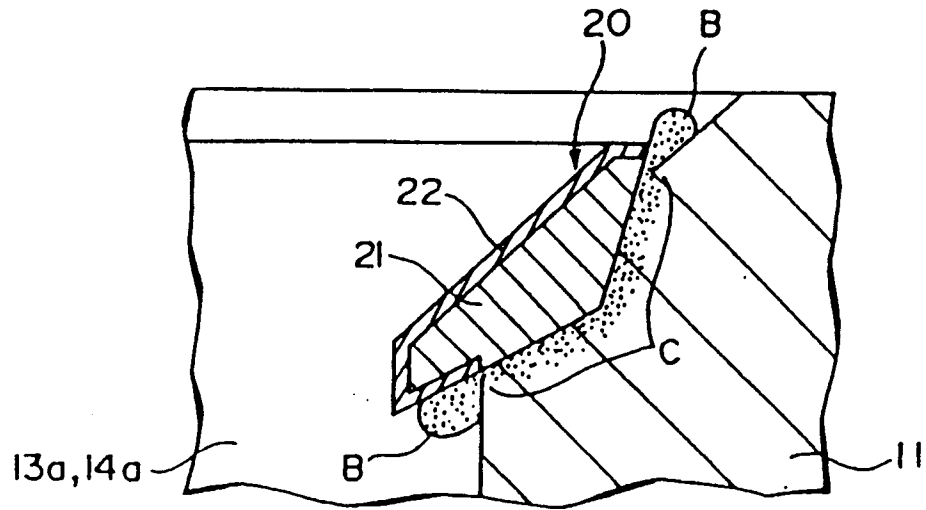


FIGURE 11

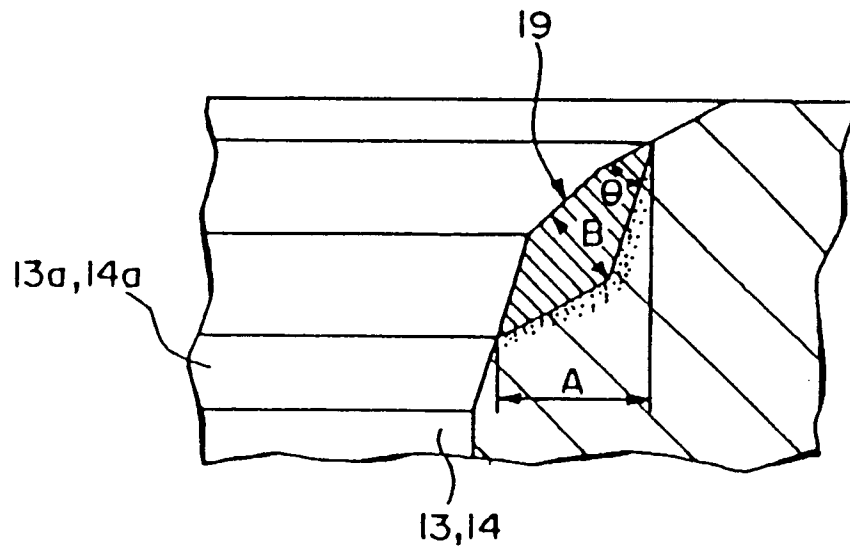


FIGURE 12

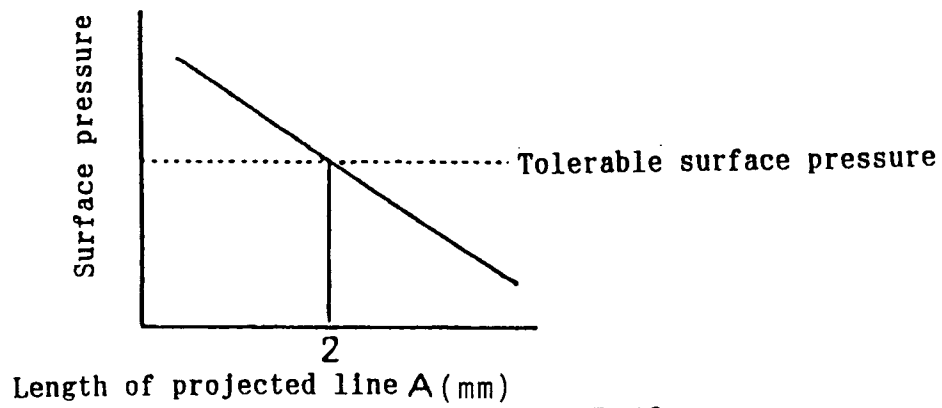


FIGURE 13

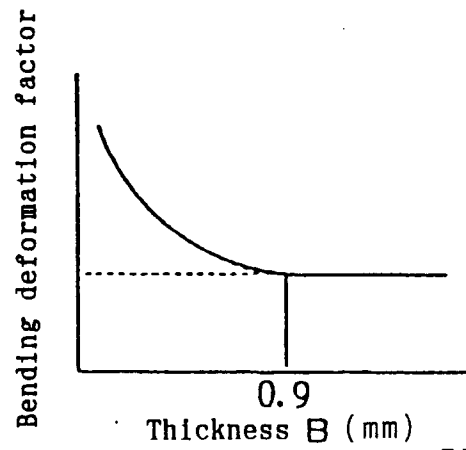


FIGURE 14

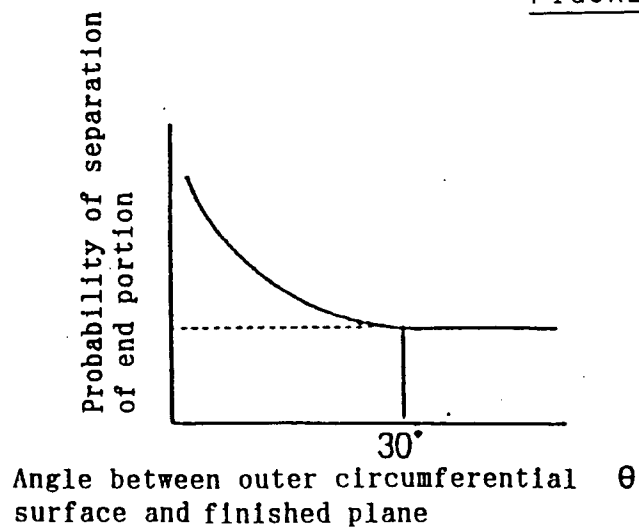


FIGURE 15

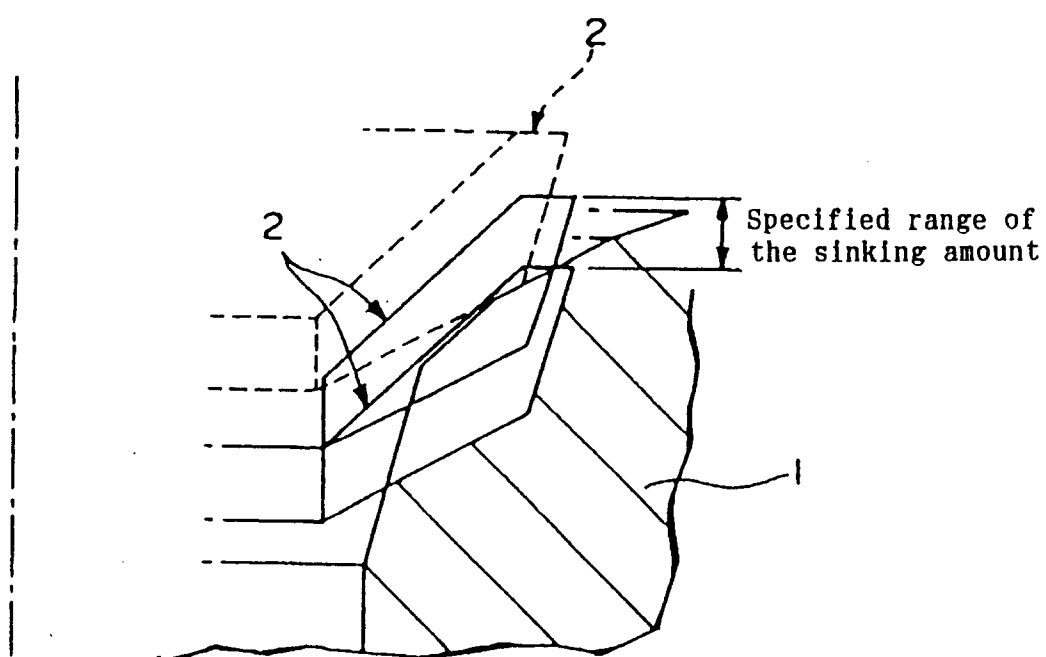


FIGURE 16

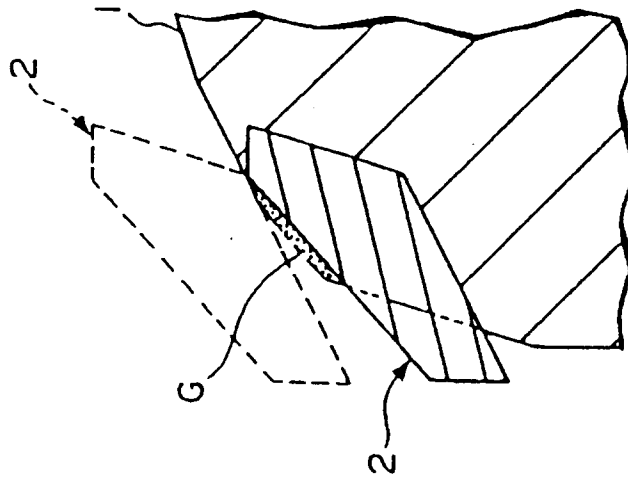


FIGURE 17 (b)

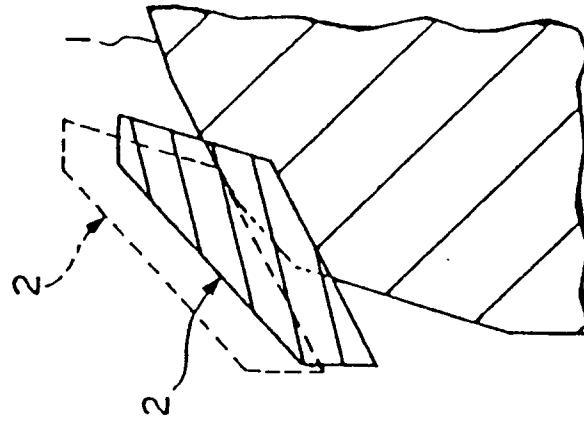


FIGURE 17 (a)

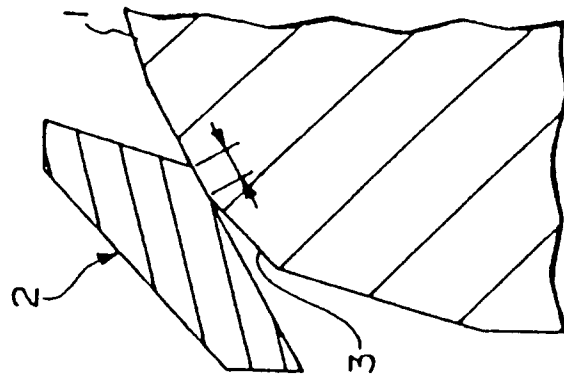


FIGURE 18 (a)

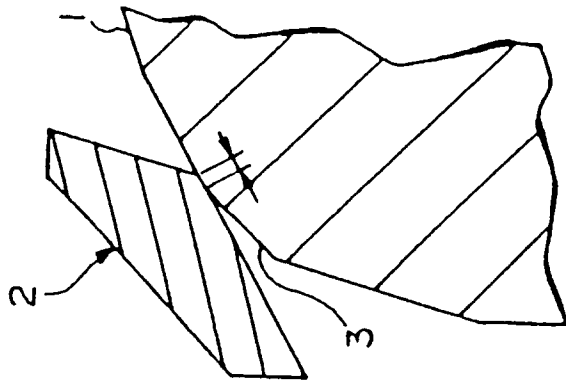


FIGURE 18 (b)

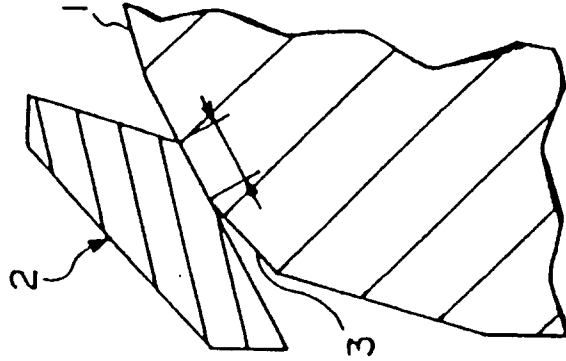


FIGURE 18 (c)

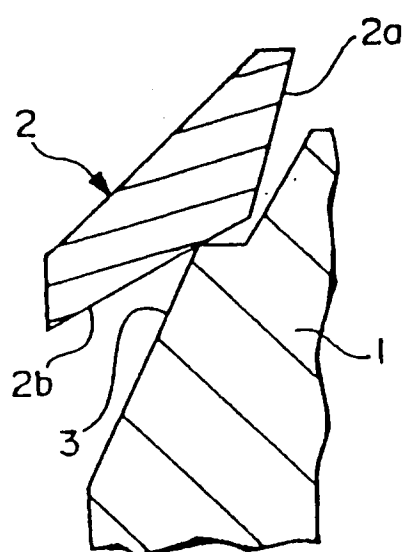


FIGURE 19 (a)

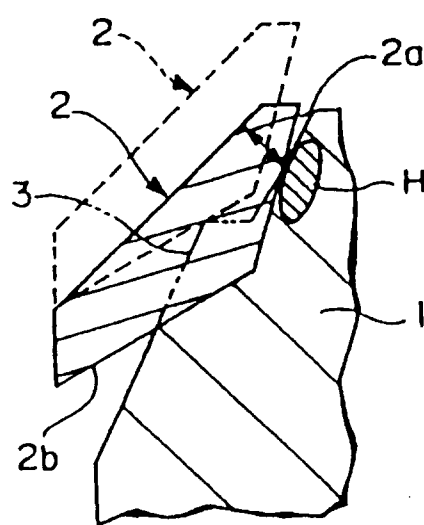


FIGURE 19 (b)



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 4721

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	EP-A-0 228 282 (TOYOTA MOTOR CO LTD) 8 July 1987 * claims 1-12; figures 1,2 *	1	F01L3/22
A	--- PATENT ABSTRACTS OF JAPAN vol. 007, no. 173 (M-232), 30 July 1983 & JP-A-58 077115 (NIPPON PISTON RING KK), 10 May 1983, * abstract *	1	
A	--- EP-A-0 195 177 (TOCCO INC) 24 September 1986 * page 10, paragraph 1 - page 14, paragraph 2; figures 1-3 *	1	
A	--- EP-A-0 051 300 (NIPPON KOKAN KK) 12 May 1982 * abstract; figure 1 *	1	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			F01L
Place of search		Date of completion of the search	Examiner
THE HAGUE		15 November 1996	Wassenaar, G
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