

AN EXHAUST VALVE FOR AN INTERNAL COMBUSTION ENGINE, AND
A METHOD OF STRENGTHENING AN ANNULAR VALVE SEAT AREA IN AN
EXHAUST VALVE

5 The present invention relates to a method of strengthening an annular valve seat area in an exhaust valve for an internal combustion engine, which exhaust valve comprises a valve disc having a first side and a second side, a valve stem extending from the first side of the valve disc, and an annular valve seat area located at the first side of the valve disc. ~~Thean exhaust valve for an~~
10 ~~internal combustion engine, the exhaust valve comprising a valve disc having a first side and a second side, a valve stem extending from the first side of the valve disc, and an annular valve seat area is located at the first side of the valve disc and, whichthe~~ annular valve seat area is of a nickel-base alloy or a chromium-base alloy and has a valve seat surface.

15 Such an exhaust valve is disclosed in US 6,295,731 where a valve blank has a valve disc of smaller diameter than the disc of the completed valve and excess material above the valve seat. The excess material is shaped as an isosceles-triangle-sectioned lobe on the valve disc covering the complete area of the valve seat. The valve blank is heated to a temperature of 530 to 600°C
20 and is forged in a die having the shape of the completed valve disc. During forging the isosceles-triangle-sectioned lobe is plastically deformed and the outer diameter of the valve disc is increased. The forging of the excess material thus causes plastic flow of all the material at the outer area of the valve disc.

EP 0 204 121 discloses an exhaust valve with a valve disc made of a
25 basic material and a welded-on hardfacing of a nickel-based or cobalt-based superalloy. An annular valve seat area is located at the middle area of the upper side of the hardfacing. After the valve disc has been machined to the final dimensions of the valve seat area, a thin layer of superalloy is melted into the surface in order to prevent corrosion attacks in the transition between the two
30 materials. The thin layer is located at the transition between the hardfacing and the basic material. The thin layer is heated and melted into the valve disc. One such thin layer is applied to the first side of the valve disc, and another such thin layer is applied to the side wall of the valve disc.

 EP 0 521 821 B1 discloses an exhaust valve comprising a valve disc
35 having a first side provided with an extending valve stem and an annular valve seat area with a valve seat surface. The annular valve seat area is of a nickel-

base alloy or a chromium-base alloy. Forging may be used to globally shape the valve seat area. Hot deformation is recommended in order to distribute carbide formations within the material in order to obtain improved corrosion resistance.

5 The book 'Diesel engine combustion chamber materials for heavy fuel operation' published in 1990 by The Institute of Marine Engineers, London, collected the experience gained from the whole industry and provided the general conclusion that the valve seat area of an exhaust valve must have high hardness.

10 WO 97/47862 discloses an exhaust valve disc having a base body of austenitic stainless steel and a valve seat area of a nickel-base

material provided by welding or by a HIP process. The yield strength of the valve seat area may be increased by cold-working of the material, such as by rolling or forging the valve seat area.

5 The present invention relates to a method of strengthening an annular valve seat area in an exhaust valve for an internal combustion engine, which exhaust valve comprises a valve disc having a first side and a second side, a valve stem extending from the first side of the valve disc, and an annular valve seat area located at the first side of the valve disc.

10 In order to improve the manufacturing of the valve seat area, at least the following steps are performed according to the present invention:

- a) a valve disc with a raw seat area is provided, which raw seat area has at least two annular protrusions separated by an intermediate annular area,
- b) the two annular protrusions are plastically deformed,
- c) the raw seat area is machined to the dimensions of the annular valve
15 seat area,
- d) the valve disc with the annular valve seat area is subjected to heat treatment involving at least an aging heat treatment.

20 The separation of the two annular protrusions by the intermediate annular area reduces the area available for the annular protrusions, and they consequently have much less volume than the above-mentioned prior art lobe, and the deformation in step b) thus requires less forces. The deformation of the protrusions in step b) and the machining in step c) form the two second annular portions in the valve seat area, and the first annular portion is located in or formed by the intermediate annular area.

25 The annular valve seat area obtained by the method has at least a first annular portion located in between two second annular portions, which first annular portion has lower hardness than the two second annular portions. The first annular portion of lower hardness has higher ductility than the two second annular portions, and the location of the first annular portion in between the two
30 second annular portions in the valve seat area allows elastic valve seat deformation to occur more in the first annular portion than in the second annular portions. The harder and less ductile second annular portions may thus be less affected by loads caused by temperature changes when the engine initiates operation or is taken out of operation or is significantly changing engine load.

35 The smaller size of the two annular protrusions also reduces the need for excess material in the raw seat area, and the valve disc with the raw seat

area can be shaped closer to the final dimensions of the valve disc and thus alloying material is saved and the need for machining in step c) is also reduced.

The plastic deformation can be effected by forging, but preferably the plastic deformation in step b) involves rolling with a cylindrically shaped roll. The cylindrically shaped roll is in contact with only a small portion of the annular protrusion at a time because the roll is arranged during rolling with its rotational axis extending in a direction approximately orthogonal to the circular path of the annular protrusion. It is a distinct advantage that the complete width of the annular protrusion is rolled simultaneously by the roll and that the roll extends to both sides of the annular protrusion because the plastically deformed material cannot just be pressed aside into a ridge but is pressed into the material of the valve seat area below the roll. It is possible to roll the raw seat area into the shape of the completed valve seat area and then perform the machining in step c) as a grinding.

As the annular protrusions are separated by the intermediate annular area the one annular protrusion is located at a larger distance from the stem than the other annular protrusion. It is naturally possible to use only a single roll for the annular protrusions and to roll both protrusions in a common rolling operation, or to roll the one protrusion first, and then roll the other protrusion. It is also possible to use a separate cylindrically shaped roll for each annular protrusion which allows the roll located at the larger distance to rotate at a slightly higher speed than the other roll.

When two rolls are used the separate cylindrically shaped rolls are preferably carried by a common rolling tool, but are allowed to rotate during rolling with mutually different rotational speeds.

The individual annular protrusion provided in step a) may have different shapes, such as a shape with a curved central portion. The top of the curve can be located at a radial position where the second annular portion should have the highest hardness.

It is an object of the present invention to improve the manufacturing of the valve seat area.

With a view to this, the initially mentioned exhaust valve according to the present invention is characterized in that the annular valve seat area has at least a first annular portion located in between two second annular portions, which first annular portion has lower hardness than the two second annular portions.

The first annular portion of lower hardness has higher ductility than the two second annular portions, and the location of the first annular portion in between the two second annular portions in the valve seat area allows elastic valve seat deformation to occur more in the first annular portion than in the second annular portions. As mentioned, the harder and less ductile second annular portions may thus be less affected by loads caused by temperature changes when the engine initiates operation or is taken out of operation or is significantly changing engine load. In particular for main propulsion engines in a vessel the engine is typically operated at almost constant engine load – typically full engine load – for several or many days in a row while sailing across seas from one destination to another, and then operated at low engine load while the vessel approaches and enters a port. Such changes in load and resulting changes in operating temperatures affect the valve disc and the valve seat area. The valve seat area is part of the first side of the valve disc and is thus facing away from the combustion chamber in the engine cylinder. The valve seat area has a conical outer surface and due to the resulting changes in thickness of the valve disc at the valve seat area the loadings caused by thermal changes of the valve disc are of significance. The first annular portion in the valve seat area reduces the amount of high hardness alloy material in the valve seat area, as the high hardness alloy material is localised in the two second annular portions.

In the prior art exhaust valves the entire valve seat area is subjected to plastically deformation in order to improve the hardness or yield

strength of the valve seat alloy. The first annular portion of lower hardness requires that plastic deformation is avoided, or not performed to the same extent as in the second annular portions. As less plastic deformation is required, the manufacturing of the valve seat area is facilitated and the plastic deformation carried out may be more precise because the volumes of material to be deformed are smaller.

~~In an embodiment—~~The average hardness at the valve seat surface at the middle of the first annular portion ~~is~~ can be at least 80 HV lower than the average hardness at the middle of the surface of at least one of the second annular portions. Although advantages are obtained also at lower differences of average hardness, such as a difference of at least 50 HV, the difference of at least 80 HV provides a suitable ductility in the first annular portion.

~~In an embodiment—~~The material of the two second annular portions ~~may have~~ has a crystallographic grain structure of cold deformation and age hardening below recrystallization temperature. The age hardening is not mandatory, but presents an advantageous manner of improving the hardness of the two second annular portions when the alloy of the valve seat area is capable of age hardening.

~~In a further embodiment—~~The material of the first annular portion ~~may have~~ has a crystallographic grain structure without cold deformation. In this ~~embodiment~~ case, the ductility of the material of the first annular portion is about as high as possible for the given alloy and geometry of the valve seat area.

It is possible to make the entire valve disc of the same alloy as the alloy in the valve seat area. For exhaust valves having large dimensions, such as an outer diameter of the valve disc of 0.10 m or more, it may be an advantage to use a base body of one alloy and provide this base body with a valve seat area of another alloy. ~~In an embodiment—~~The valve disc carrying the annular valve seat area may comprises a base body of stainless steel. The stainless steel provides suitably high strength and the stainless steel alloys are readily available.

~~In an embodiment—~~The valve disc may comprises at its second side a layer of a hot corrosion resistant material. The second side of the valve

disc faces the combustion chamber and is thus subjected to high temperatures in operation and also to corrosive combustion residues adhering to the surface of the disc. The layer of hot corrosion resistant material may improve the life time of the exhaust valve.

5 ~~In another aspect, the present invention relates to a method of strengthening an annular valve seat area in an exhaust valve for an internal combustion engine, which exhaust valve comprises a valve disc having a first side and a second side, a valve stem extending from the first side of the valve disc, and an annular valve seat area located at the first side of the valve disc.~~

10 ~~In order to improve the manufacturing of the valve seat area, at least the following steps are performed according to the present invention:~~

~~a) a valve disc with a raw seat area is provided, which raw seat area has at least two annular protrusions separated by an intermediate annular area,~~

~~b) the two annular protrusions are plastically deformed,~~

15 ~~c) the raw seat area is machined to the dimensions of the annular valve seat area,~~

~~d) the valve disc with the annular valve seat area is subjected to heat treatment involving at least an aging heat treatment.~~

20 ~~The separation of the two annular protrusions by the intermediate annular area reduces the area available for the annular protrusions, and they consequently have much less volume than the above mentioned prior art lobe, and the deformation in step b) thus requires less forces. The deformation of the protrusions in step b) and the machining in step c) form the two second annular portions in the valve seat area, and the first annular portion is located in or~~
~~25 formed by the intermediate annular area.~~

~~The smaller size of the two annular protrusions also reduces the need for excess material in the raw seat area, and the valve disc with the raw seat area can be shaped closer to the final dimensions of the valve disc and thus alloying material is saved and the need for machining in step c) is also reduced.~~

30 ~~The plastic deformation can be effected by forging, but preferably~~

the plastic deformation in step b) involves rolling with a cylindrically shaped roll. The cylindrically shaped roll is in contact with only a small portion of the annular protrusion at a time because the roll is arranged during rolling with its rotational axis extending in a direction approximately orthogonal to the circular path of the annular protrusion. It is a distinct advantage that the complete width of the annular protrusion is rolled simultaneously by the roll and that the roll extends to both sides of the annular protrusion because the plastically deformed material cannot just be pressed aside into a ridge but is pressed into the material of the valve seat area below the roll. It is possible to roll the raw seat area into the shape of the completed valve seat area and then perform the machining in step c) as a grinding.

As the annular protrusions are separated by the intermediate annular area the one annular protrusion is located at a larger distance from the stem than the other annular protrusion. It is naturally possible to use only a single roll for the annular protrusions and to roll both protrusions in a common rolling operation, or to roll the one protrusion first, and then roll the other protrusion. It is also possible to use a separate cylindrically shaped roll for each annular protrusion which allows the roll located at the larger distance to rotate at a slightly higher speed than the other roll.

When two rolls are used the separate cylindrically shaped rolls are preferably carried by a common rolling tool, but are allowed to rotate during rolling with mutually different rotational speeds.

The individual annular protrusion provided in step a) may have different shapes, such as a shape with a curved central portion. The top of the curve can be located at a radial position where the second annular portion should have the highest hardness.

Examples of embodiments will be described in further detail in the following with reference to the schematic drawings, on which

Fig. 1 illustrates a vertical section through a cylinder of an internal combustion engine,

Fig. 2 depicts an exhaust valve according to the present invention,

Fig. 3 is a cross sectional view of a valve seat raw area,

Fig. 4 illustrates a prior art rolling method for a valve seat area,

Fig. 5 is a cross sectional view through the valve seat raw area after applying the prior art rolling method of Fig. 4,

Fig. 6 illustrates the hardness distribution in the completed valve
5 seat area manufactured with the prior art rolling method of Fig. 4,

Fig. 7 illustrates a section through an outer area of the exhaust valve disc and a stationary valve housing part,

Fig. 8 illustrates a section through a first embodiment of raw seat area having two annular protrusions separated by an intermediate annular area
10 in accordance with the method of the present invention,

Fig. 9 is an illustration of a rolling tool and a valve disc for the method according to the present invention,

Fig. 10 illustrates a vertical cross section through a valve seat area in according to the present invention,

15 Fig. 11 illustrates the hardness distribution in a rolled valve seat area treated with the method of the present invention, and

Fig. 12 illustrates a section corresponding to Fig. 8 through a second
embodimentversion of raw seat area in accordance with the present invention.

When alloys are specified or alloying components mentioned in the
20 present description, components are stated in percent by volume (vol-%) but only denoted %.

An exhaust valve 1 is viewed in Fig. 1 in an open position allowing intake air to be supplied from a turbocharger 2 to a scavenge air receiver 3 via a scavenge air cooler 4 and a water mist catcher 5. The intake and scavenge air
25 flows from the scavenge air receiver through a row of scavenge air ports 6 in the lower end of a cylinder 7 and upwards through the cylinder in a swirling motion and up towards the upper portion of the cylinder, while at the same time pressing out hot combustion gasses via the open exhaust valve and into the exhaust gas receiver 8. The flow of hot combustion gasses past the valve seats
30 of the exhaust valve can occur at high gas speeds, in particular when the valve opens and closes.

The exhaust valve 1 is mounted in an exhaust valve housing 9 that is fixed to a cylinder cover 10 at the top of the cylinder. In the closed

PATENT CLAIMS

1. An exhaust valve for an internal combustion engine, the exhaust valve comprising a valve disc having a first side and a second side, a valve stem extending from the first side of the valve disc, and an annular valve seat area located at the first side of the valve disc, which annular valve seat area is of a nickel-base alloy or a chromium-base alloy and has a valve seat surface, wherein the annular valve seat area has at least a first annular portion located in between two second annular portions, which first annular portion has lower hardness than the two second annular portions.
2. An exhaust valve according to claim 1, wherein the average hardness at the valve seat surface at the middle of the first annular portion is at least 80 HV lower than the average hardness at the middle of the surface of at least one of the second annular portions.
3. An exhaust valve according to claim 1 or 2, wherein the material of the two second annular portions has a crystallographic grain structure of cold deformation and age hardening below recrystallization temperature.
4. An exhaust valve according to one or more of claims 1 to 3, wherein the material of the first annular portion has a crystallographic grain structure without cold deformation.
5. An exhaust valve according to one or more of claims 1 to 4, wherein the valve disc carrying the annular valve seat area comprises a base body of stainless steel.
6. An exhaust valve according to one or more of claims 1 to 5, wherein the valve disc at its second side comprises a layer of a hot corrosion resistant material.
7. A method of strengthening an annular valve seat area in an exhaust valve for an internal combustion engine, which exhaust valve comprises a valve disc having a first side and a second side, a valve stem extending from the first side of the valve disc, and an annular valve seat area located at the first side of the valve disc, wherein at least the following steps are performed:
- a) a valve disc with a raw seat area is provided, which raw seat

area has at least two annular protrusions separated by an intermediate annular area,

b) the two annular protrusions are plastically deformed,

5 c) the raw seat area is machined to the dimensions of the annular valve seat area,

d) the valve disc with the annular valve seat area is subjected to heat treatment involving at least an aging heat treatment.

8. A method of strengthening an annular valve seat area in an exhaust valve according to claim 7, wherein the plastic deformation in step
10 b) involves rolling with a cylindrically shaped roll.

9. A method of strengthening an annular valve seat area in an exhaust valve according to claim 8, wherein a separate cylindrically shaped roll is provided for each annular protrusion.

10. A method of strengthening an annular valve seat area in an
15 exhaust valve according to claim 9, wherein the separate cylindrically shaped rolls are carried by a common rolling tool, but are allowed to rotate during rolling with mutually different rotational speeds.

11. A method of strengthening an annular valve seat area in an
20 exhaust valve according to one or more of claims 7 to 10, wherein the individual annular protrusion provided in step a) has a curved central portion.

P A T E N T C L A I M S

1. A method of strengthening an annular valve seat area in an exhaust valve for an internal combustion engine, which exhaust valve comprises a valve disc having a first side and a second side, a valve stem extending from the first side of the valve disc, and an annular valve seat area located at the first side of the valve disc, wherein at least the following steps are performed:
- a) a valve disc with a raw seat area is provided, which raw seat area has at least two annular protrusions separated by an intermediate annular area,
 - b) the two annular protrusions are plastically deformed,
 - 10 c) the raw seat area is machined to the dimensions of the annular valve seat area,
 - d) the valve disc with the annular valve seat area is subjected to heat treatment involving at least an aging heat treatment.
2. A method of strengthening an annular valve seat area in an exhaust valve according to claim 1, wherein the plastic deformation in step b) involves rolling with a cylindrically shaped roll.
3. A method of strengthening an annular valve seat area in an exhaust valve according to claim 2, wherein a separate cylindrically shaped roll is provided for each annular protrusion.
- 20 4. A method of strengthening an annular valve seat area in an exhaust valve according to claim 3, wherein the separate cylindrically shaped rolls are carried by a common rolling tool, but are allowed to rotate during rolling with mutually different rotational speeds.
- 25 5. A method of strengthening an annular valve seat area in an exhaust valve according to one or more of claims 1 to 4, wherein the individual annular protrusion provided in step a) has a curved central portion.

AN EXHAUST VALVE FOR AN INTERNAL COMBUSTION ENGINE, AND A
METHOD OF STRENGTHENING AN ANNULAR VALVE SEAT AREA IN AN EX-
HAUST VALVE

5 A B S T R A C T

10 An annular valve seat area in an exhaust valve for an internal combustion engine is strengthened by performing at least the following steps: a) a valve disc with a raw seat area is provided, which raw seat area has at least two annular pro-
trusions (37) separated by an intermediate annular area (38), b) the two annu-
lar protrusions (37) are plastically deformed, c) the raw seat area is machined
to the dimensions of the annular valve seat area (11), and d) the valve disc with
the annular valve seat area (11) is subjected to heat treatment involving at least
an aging heat treatment.

15

An exhaust valve for an internal combustion engine comprises a valve disc hav-
ing a first side (14) and a second side (16), a valve stem extending from the
first side of the valve disc, and an annular valve seat area (11) located at the
first side of the valve disc. The annular valve seat area (11) is of a nickel-base
20 alloy or a chromium-base alloy and has a valve seat surface. The annular valve
seat area has at least a first annular portion (43) located in between two second
annular portions (42). The first annular portion has lower hardness than the two
second annular portions.

25 (Fig. 108)