

Piston for a large-size engine and method  
for the production of a wear-resistant layer in such a piston

This invention, according to a first invention concept, relates to a piston for a large-size engine, in particular a large-size two-stroke cycle diesel engine, having a piston crown made of a ferrous material and provided with circumferential piston ring grooves, each of them designed for receiving a piston ring, with at least the uppermost of such grooves, next to the combustion chamber, being provided on its lateral surface away from the combustion chamber with a wear-resistant layer.

This invention, according to a further invention concept, relates to a method for the production of a wear-resistant layer on such a piston, such wear-resistant layer being applied to the ferrous material of the associated piston crown in the area of that lateral surface of the piston ring groove which is disposed away from the combustion chamber.

On known arrangements of this kind, the wear-resistant layer is designed as a hard chrome plating which, as a rule, is applied by way of an electrogalvanic process. This hitherto used wear-resistant layer, however, under high loading in the form of high pressure and high temperatures and/or a high concentration of abrasive particles in the charging air, etc., has proved to be of insufficient durability. The result is a comparatively short service life.

On these premises it is the object of the present invention to improve a piston of the kind described initially above in such a way that, using simple and low cost means, a comparatively long service life of the wear-resistant layer is achieved, and to make provision for a simple method of applying a wear-resistant layer in accordance with the invention.

The first part of the above-mentioned object in connection with the generic-term piston is achieved in that the wear-resistant layer contains a metallic matrix in which load bearing particles are embedded, with at least such load bearing particles possessing a degree of hardness that is greater than that of chromium.

The hardness and, along with it, the durability of the wear-resistant layer is in the first place influenced by the properties of the load bearing particles. Because these possess a greater hardness than chromium or chrome oxide, the measures according to this invention also provide for an increased durability as compared to the known protective chromium layer. Owing to the fact that the hard load bearing particles are embedded in a softer matrix it is nevertheless ensured that the wear-resistant layer possesses a sufficient degree of ductility.

Since the hard load bearing particles are embedded in a matrix, it will be possible for the formation of the said load bearing particles to advantageously use such materials which in the form of solids cannot in situ be produced in the desired thickness. The measures according to the invention thus permit the production of a wear-resistant layer of any desired thickness, and with the desired high load bearing capacity, which thus in an advantageous manner results in a long service life thereof.

Advantageous embodiments and expedient further developments of the generic measures are defined in the sub-claims. Thus the load bearing particles may expediently be of rounded configuration. This ensures that they will not act in the manner of abrasive grains, so that undesirable wear of the associated piston ring is avoided. At the same time, a reliable support and anchorage of the load bearing particles in the matrix is ensured.

A further expedient measure may consist in making provision that the load bearing particles have a diameter of between 20 and 60 microns. This enables a comparatively high content and a homogeneous distribution of the load bearing particles. Expediently the amount of load bearing particles in the wear-resistant layer may make up 50 percent by volume.

A further development of the generic measures may consist in that the matrix is made of an alloy containing Ni, Cr, B and Si as constituent elements. Such an alloy in an advantageous manner results in comparatively great hardness of the matrix. In addition, the said material also possesses good flow characteristics, a factor that ensures simple application by a spray process and facilitates achieving a uniform thickness of the wear-resistant layer.

The load bearing particles may advantageously consist of a ceramic material, preferably tungsten carbide. These measures in a particularly cost effective manner result in very hard load bearing particles.

The wear-resistant layer should expediently have a thickness of 0.3 to 0.5 mm. This ensures that the amount of clearance in the piston ring groove will not be getting too large in the course of time by wear of the wear-resistant layer.

A further advantageous embodiment of the generic measures may consist in making provision that the density of the wear-resistant layer increases from radially inwards in the direction of radially outwards. Loading is highest in the radially outer range of the piston ring groove, which means that this range must have the highest load bearing capacity, which

condition will be fulfilled by an increasing density in the radially outward direction. The aforesaid measures will thus ensure that the density distribution over the radial width of the piston ring groove approximately corresponds to the loading, so that a comparatively uniform wear over the entire width is to be expected. This will contribute towards preventing undesirable canting of the piston ring in the groove.

A further advantageous measure may consist in hardening the ferrous material of the piston crown at least in the region adjacent to the wear-resistant layer. This will counteract any tendency of the wear-resistant layer to sink into the base material and at the same time avoid an excessive difference in hardness between the wear-resistant layer and the base material underneath, a factor that will likewise have a favourable effect on durability.

The second part of the initially mentioned object of the invention in connection with the generic method is achieved in that the material forming the wear-resistant layer, which consists of an aggregation with a metallic alloy forming a matrix and, incorporated in the latter, a plurality of load bearing particles having a greater hardness than chromium, preferably a greater hardness than DPH 1600, is sprayed onto a previously prepared lateral surface of the piston ring groove, with the matrix-forming metal alloy being present in a molten state and that, either subsequently or simultaneously, the sprayed-on material is subjected to a suitable heat treatment.

Since the material forming the wear-resistant layer is sprayed directly onto the associated lateral surface of the piston ring groove, good contact with the base material will be obtained. Subsequent heat treatment ensures that any differences in thickness which might result from the spraying angle will be reliably compensated for. At the same time, the heat treatment serves to obtain the desired hardening of the base material.

It may be expedient to alter the spraying angle over the width of the piston ring groove, using a steeper spraying angle in the radially outer range than in the radially inward range. This makes it possible in an advantageous manner to obtain a desired greater density in the radially outer range.

The afore-mentioned object in connection with the generic method may further be achieved in that the material forming the wear-resistant layer, which consists of an aggregation with a metallic alloy forming a matrix and, incorporated in the latter, a plurality of load bearing particles having a greater hardness than chromium, preferably a greater hardness than DPH

1600, is applied onto the prepared lateral surface of the piston ring groove in the form of a binder material and that a subsequent heat treatment is carried out during which the metal alloy forming the matrix is melted and the binder material burned. This method avoids the difficulties in connection with a spray process which may particularly arise in comparatively deep, narrow piston ring grooves.

It may be expedient to proceed in such a way that, from the material forming the wear-resistant layer, in combination with the binder, green compacts having the form of a segment of the annular wear-resistant layer are produced which are placed onto the base material and then subjected to heat treatment. The production of such green compacts facilitates handling.

A further, in any case advantageous, measure may consist in that heat treatment is carried out by supplying a shielding gas. This will prevent oxidation, in particular in the bonding zone with the base material, thus ensuring good adherence of the wear-resistant layer to the base material.

Further advantageous embodiments and expedient developments of the main-claim measures will be evident from the remaining sub-claims and from the description of an example given below in conjunction with the accompanying drawings, wherein

- Figure 1 shows a section of a piston of a large-size two-stroke cycle diesel engine;
- Figure 2 shows an enlarged view of a section of the wear-resistant layer of the arrangement according to Figure 1;
- Figure 3 shows an enlarged view of a piston ring groove of the arrangement according to Figure 1 with a wear-resistant layer partially sprayed thereon;
- Figure 4 shows an enlarged view of a piston ring groove of the arrangement according to Figure 1 during heat treatment of the wear-resistant layer; and
- Figure 5 shows a plan view of the segment-shaped wear-resistant green compacts, placed in the piston ring groove.

The main field of application of this invention is the realm of large-size two-stroke cycle diesel engines and similar large size engines. The principal design and the method of operation of such engines are known to the art.

Figure 1 shows the upper part of a piston 2, i.e. the portion referred to as the piston crown 1, of a large-size two-stroke cycle diesel engine. In large-size engines as described in this invention the piston crown 1 is made of a ferrous material, such as grey-cast iron or cast steel. The piston crown 1 of each such piston 2 is provided with a piston ring package comprising several piston rings 3 arranged underneath one another, which piston ring package seals the gap between the outer surface of the piston crown 1 and the surface of a cylinder liner receiving the piston 2. Each of the piston rings 3 is received in an associated piston ring groove 4 of the piston crown 1.

At least the uppermost piston ring groove 4, that is to say the piston ring groove 4 next to the combustion chamber limited by the piston 2, is in the area of its lower surface, i.e. the lateral surface away from the combustion chamber, provided with a wear-resistant layer 5 on which the associated piston ring 3 rests. It will be expedient to provide several adjacent, upper piston ring grooves 4 with such a wear-resistant layer 5. In the embodiment illustrated, all piston ring grooves 4 are provided with such a wear-resistant layer 5.

The wear-resistant layer 5, as can best be seen in the enlarged view shown in Figure 2, contains load bearing particles 6 possessing a great degree of hardness and embedded in a metallic matrix 7 which is bonded to the ferrous base material forming the piston crown 1. The hardness of the load bearing particles 6 is greater than that of chromium or chrome oxide which forms on the surface of chromium. For this purpose, load bearing particles 6 are used whose degree of hardness is greater than DPH 1600. The material forming the matrix 7 possesses a lower degree of hardness than the load bearing particles 6, which ensures sufficient ductility of the wear-resistant layer 5. A suitable material for forming the matrix 7 is an alloy containing Ni, Cr, Si, Fe, B and C. Such an alloy expediently contains 74 % Ni, 15 % Cr, 4 % Si, 3.5 % Fe, 3 % B and 0.5 % C.

The load bearing particles 6 expediently consist of a ceramic material which can be provided at low cost. Experimentation with load bearing particles 6 made of tungsten carbide has yielded good results.

The load bearing particles 6, as is indicated in Figure 2, are expediently of rounded to ball-shaped configuration. The diameter of the load bearing particles 6 is between 20 and 60 microns. Expediently the load bearing particles 6 are homogeneously distributed all over the matrix 7. The proportion of load bearing particles 6 in the wear-resistant layer 5 may be up to 80 percent by volume. Experimentation using an amount of 50 percent by volume has yielded good results.

The degree of thickness of the wear-resistant layer 5 is calculated in such a manner that the permissible clearance between the piston ring 3 and the piston ring groove 4 will not be exceeded when the wear-resistant layer 5 has worn-off. Expediently, the wear-resistant layer 5 should therefore possess a maximum thickness of 1 mm, preferably 0.3 to 0.5 mm. In the case of particularly large arrangements, the aforesaid thickness of the wear-resistant layer 5 lies closer to the upper limit and vice versa.

The wear-resistant layer 5 may have a homogenous density over its entire width. Expediently, however, the course of the density across the width roughly corresponds to the course of the loading across the width. Accordingly, the density increases from radially inwards in a radially outward direction and is highest in the range of the outer rim of the piston ring groove 4. It will thus be ensured that wear is essentially uniform across the width of the piston ring groove, so that the associated piston ring 3 is prevented from tilting and canting.

The wear-resistant layer 5, as can further be seen from Figure 1, is designed as a filling of a pocket formed by a step 8 integrated in the base material of the piston crown 1, which pocket is open at the top and extends in a radial direction from an inner web 9 to the outer rim of the associated piston ring groove 4. The flank of the web 9 facing the step 8 is inclined, so that the step 8 and the wear-resistant layer 5 filling up such step 8 form a pointed end in a radially inward direction. Between the web 9 and the radially inner limit of the piston ring groove 4, provision is made for a circumferential groove 10 which may serve to prevent notch stresses and heat fracture.

The wear-resistant layer 5, as is indicated in Figure 3, can be sprayed onto the base material by means of such spray methods as plasma spraying or high-velocity oxyfuel (HVOF) spraying. For this purpose, a spray device, indicated in the drawing by a spray head 11, is used, which serves to spray the material forming the wear-resistant layer 5 into the pocket formed by the step 8, as is indicated by spray jets 12. The spray angle, as indicated by a

swivel arrow 13 in Figure 3, may be varied in such a manner that it is steeper in the range of the outer rim of the piston ring groove 4 than in the range of the inner rim of the wear-resistant layer 5. In this manner, a higher degree of density of the wear-resistant layer 5 will be obtained in the range of the outer rim of the wear-resistant layer 5 than in the range of the inner rim.

During the spray process, the material forming the matrix 7 is present in liquid, that is to say in molten form and enters into a bond with the base material when solidifying. The load bearing particles 6 are dispersed in the liquid matrix material and are thus sprayed on together with the latter. When the matrix material has solidified, the load bearing particles will be fixed in the matrix.

The spray process is followed by heat treatment which is indicated in Figure 4. For this purpose, provision is made for a heating device 14 inserted into the piston ring groove 4 and serving to heat the newly sprayed-on wear-resistant layer 5. The heating device 14 comprises at least one comparatively short heater segment which is inserted into the piston ring groove 4 and is inductively heatable, that is to say it is provided with at least one coil to which an electric current can be applied. During heat treatment the piston crown comprising the piston ring grooves 4 is rotated in such a manner that the entire circumference is subjected to heat treatment. As a rule, one full rotation will be sufficient. This process is expediently repeated for each piston ring groove 4 fitted with a wear-resistant layer 5. It would likewise be conceivable to simultaneously carry out the heat treatment for several or all piston ring grooves 4 possessing a wear-resistant layer. Provision may also be made for several heater segments distributed over the circumference which would reduce the angle of rotation. Instead of providing an inductively heatable heating device it would, of course, be equally imaginable to make provision for a heating device comprising one or more burners, or a laser heating device.

The temperature obtainable by means of the heater device 14 is higher than the melting point of the material forming the matrix 7. In the example described, such temperature should be between 1000° and 1200° Celsius. Such heat treatment will compensate for slight differences in thickness which cannot be avoided during the spray process. At the same time, the range 15 of the base material immediately adjacent to the wear-resistant layer 5 is hardened, as is indicated by a broken line in Figure 4. It may be expedient to design the heater device 14 and to carry out the heat treatment in such a manner that not only the

range 15 at the lower lateral flank of the piston ring groove 4 is hardened, but also the range at the upper lateral flank, as is likewise indicated by a broken line 16 in Figure 4.

In the example illustrated, heat treatment is carried out after the spray process. It would, however, likewise be possible to carry out the heat treatment during the spray process itself. In any case, the spray process and the heat treatment are carried out in a shielding gas atmosphere, so that oxidation is prevented. As is indicated in Figures 3 and 4, the shielding gas, for example argon, may be supplied by the nozzles 17 or 18, which are associated with the spray head 11 or the heater device 14, respectively, and which are connected with a shielding gas source not shown here in detail.

In order to prevent undesired coating of the web 9 and the groove 10 as well as of the radially inner wall of the piston ring groove 4 when the wear-resistant layer is sprayed on, provision may be made for a suitable covering 21, as is shown in Figure 3. Such covering may consist in a ring, inserted into the piston ring groove 4 and comprising several segments. Along its circumference the covering is treated in such a manner or consists of such a material, for example brass, that bonding thereof with the wear-resistant layer 5 is prevented. The covering greatly facilitates the spray process .

A further possible method of applying the wear-resistant layer 5 may consist in that the material forming the wear-resistant layer 5, that is to say the matrix material containing the load bearing particles 6, is placed on the prepared, lower lateral flank of the associated piston ring groove 4 in a form bonded by means of a binder or in a presintered form, and that subsequent heat treatment is carried out during which the metal alloy will be melted and the binder burned .Such a method prevents the difficulties likely to be expected during the spray process, in particular in the case of very deep and narrow piston ring grooves where the use of comparatively small spray angles would be required.

The binder may be designed in such a manner that, together with the material forming the wear-resistant layer 5, it forms a paste which can be spread on the associated lateral flank of a piston ring groove. It is, however, likewise conceivable to develop an intermediate product in the form of solid, plate-like or strip-like green compacts which are placed in the associated piston ring groove 4. In either case, subsequent heat treatment is carried out during which the matrix material is melted and the binder burned .The latter may, for example, consist of diluted polyvinyl alcohol (PVA), silicone or latex.

The green compacts described above may expediently be produced in the form of segments 19 of the annular wear-resistant layer 5, as is evident from Figure 5. Several adjacent segments 19 can then accordingly be formed to a ring which may be inserted into the piston ring groove 4, with the web 9 representing a reliable inner abutment surface for the green compacts 19. The groove 10 which is located radially inside of the web 9 will thus in an advantageous manner permit the heat treatment to be restricted to the range of the pocket formed by the step 8. The groove 10 thus practically represents an untreated area serving as a precautionary measure against heat fracture .

Heat treatment may be carried out by means of an electric heating device as described above, or a heating device provided with burners or a laser device and is expediently likewise carried out in a shielding gas atmosphere. The obtainable temperature, in any case, must be above melting point of the matrix material, that is to say above 1000 °C to 1200 °C. To ensure good, uniform distribution of the matrix material, it should possess good flow characteristics which is the case with a metal alloy containing the elements Ni, Cr, B and Si. The quantities of the individual elements may correspond to those in the example described above. To improve the flow characteristics it may be expedient in some cases to add a so-called flux.

In order to prevent the liquid material from dripping off over the radially outer rim of the respective piston ring groove 4 when the wear-resistant layer 5 is sprayed on or melted on, the pocket formed by the step 8 may on its radially outer circumference be limited by a circumferential cover means 20 which is attached for the duration of the application process and can be removed afterwards, that is to say after solidification of the wear-resistant layer 5, as is indicated in the Figures 3 to 5. Such cover means may be a ring comprising several segments, which on its inside is treated in such a manner or consists of such a material that bonding with the wear-resistant layer 5 is prevented.

Alternatively, it would likewise be conceivable that the wear-resistant layer 5 is formed by soldered-on segments which have previously been formed by molten matrix material and load bearing particles embedded therein.

**Patent Claims**

1. A piston for a large-size engine, in particular a large-size two-stroke cycle diesel engine, having a piston crown (1) made of a ferrous material and provided with circumferential piston ring grooves (4), each of them designed for receiving a piston ring (3), with a least the uppermost of such grooves (4), next to the combustion chamber, being provided on its lateral surface away from the combustion chamber with a wear-resistant layer (5), **characterised in that** the wear-resistant layer (5) contains a metallic matrix (7) in which load bearing particles (6) are embedded, with such matrix (7) containing at least Ni, Cr, B and Si as constituent elements, and with at least the load bearing particles (6) having a greater hardness than chromium, and further that the wear-resistant layer (5) is designed as a filling of a step (8) integrated in the base material of the piston crown (1), which step extends in a radial direction from an inner web (9) to the outer rim of the associated piston ring groove (4).
2. A piston according to Claim 1, **characterised in that** the step (8) and the wear-resistant layer (5) filling up such step (8) form a pointed end in a radially inward direction.
3. A piston according to any of the preceding Claims, **characterised in that** the load bearing particles (6) have a greater hardness than DPH 1600.
4. A piston according to any of the preceding Claims, **characterised in that** the load bearing particles (6) are of rounded shape.
5. A piston according to any of the preceding Claims, **characterised in that** provision is made for a homogeneous distribution of the load bearing particles (6) in the matrix (7).
6. A piston according to any of the preceding Claims, **characterised in that** the proportion of load bearing particles (6) in the wear-resistant layer (5) is up to 80 percent by volume.
7. A piston according to Claim 6, **characterised in that** the proportion of load bearing particles (6) in the wear-resistant layer (5) is 50 percent by volume.

8. A piston according to any of the preceding Claims, **characterised in that** the metal alloy forming the matrix (7) contains 74 % Ni, 15 % Cr, 4 % Si, 3.5 % Fe, 3 % B and 0.5 % C.
9. A piston according to any of the preceding Claims, **characterised in that** the load bearing particles (6) consist of a ceramic material.
10. A piston according to Claim 9, **characterised in that** the load bearing particles (6) consist of tungsten carbide.
11. A piston according to any of the preceding Claims, **characterised in that** the thickness of the wear-resistant layer (5) is up to 1 mm.
12. A piston according to Claim 11, **characterised in that** the thickness of the wear-resistant layer (5) is between 0.3 and 0.5 mm.
13. A piston according to any of the preceding Claims, **characterised in that** the density of the wear-resistant layer (5) increases from radially inwards in the direction of radially outwards.
14. A piston according to any of the preceding Claims, **characterised in that** the base material receiving the wear-resistant layer (5) is hardened in at least the area immediately adjacent to the wear-resistant layer (5).
15. A piston according to any of the preceding Claims, **characterised in that** the base material possesses a hardened area (15, 16) within the range of both lateral flanks of the piston ring groove (4).
16. A piston according to Claim 14 or 15, **characterised in that** the base material in the area of the radially inner surface of the piston ring groove (4) is not hardened.
17. A piston according to any of the preceding Claims, **characterised in that** the web (9) is separated from the radially inward surface of the piston ring groove (4) by a circumferential groove (10).

18. A piston according to any of the preceding Claims, **characterised in that** several upper piston ring grooves (4) of a piston ring package are provided with a wear-resistant layer (5).
19. A piston according to Claim 18, **characterised in that** all piston ring grooves (4) are provided with a wear-resistant layer (5).
20. A method for the production of a wear-resistant layer on a piston according to any of the preceding Claims, such wear-resistant layer (5) being applied to the ferrous material of the piston crown (1) in the area of that lateral surface of the associated piston ring groove (4) which is disposed away from the combustion chamber, **characterised in that** the material forming the wear-resistant layer (5), which consists of a metallic alloy forming a matrix (7) and, incorporated in the latter, a plurality of load bearing particles (6) having a greater hardness than chromium, is sprayed onto a previously prepared lateral surface of the piston ring groove (4), with the metal alloy forming the matrix (7) being present in a molten state and that, either subsequently or simultaneously, the sprayed-on material is subjected to heat treatment.
21. A method according to Claim 20, **characterised in that** the spray angle over the width of the wear-resistant layer (5) is varied, with such spray angle being steeper in the radially outward range than in the radially inward range.
22. A method according to any of the preceding Claims 20 or 21, **characterised in that**, during the spray process, the areas of the piston ring groove (4) which are adjacent to the radially inward rim of the wear-resistant layer (5) are covered by a covering (21.)
23. A method for the production of a wear-resistant layer on a piston according to any of the preceding Claims 1 to 20, with the wear-resistant layer (5) being applied to the ferrous material of the piston crown (1) in the area of that lateral surface of the associated piston ring groove (4) which is disposed away from the combustion chamber, **characterised in that**, the material forming the wear-resistant layer (5), which consists of a metallic alloy forming a matrix (7) and, incorporated in the latter, a plurality of load bearing particles (6) having a greater hardness than chromium, is applied onto the prepared lateral surface of the piston ring groove (4) in the form of a

binder material and that a subsequent heat treatment is carried out during which the metal alloy forming the matrix (7) is melted and the binder material burned.

24. A method according to Claim 23, **characterised in that** from the material forming the wear-resistant layer (5), in combination with the binder, green compacts having the form of a segment (19) of the annular wear-resistant layer (5) are produced which are placed onto the associated lateral flank of the piston ring groove (4) and then subjected to heat treatment.
25. A method according to any of the preceding Claims 20 to 24, **characterised in that** the heat treatment is carried out by supplying a shielding gas.
26. A method according to any of the preceding Claims 20 to 25, **characterised in that** the heat treatment is carried out at a temperature above melting point of the material forming the matrix (7).
27. A method according to any of the preceding Claims 20 to 26, **characterised in that** the heat treatment is carried out by using an inductively heatable heating device (14) extending over and across a part of the circumference of the piston ring groove (4) and along which the wear-resistant layer (5) is moved by turning the piston crown (1).
28. A method according to any of the preceding Claims 20 to 26, **characterised in that** the heat treatment is carried out by using at least one burner and/or laser device.
29. A method according to any of the preceding Claims 20 to 28, **characterised in that** the wear-resistant layer (5) is inserted into a step (8) incorporated in the base material.
30. A method according to Claim 29, **characterised in that** the step (8) is limited by a circumferential ring (20) on its radially outward side until the wear-resistant layer (5) has solidified.