

## **Wear protection device and method for the production thereof**

The invention relates to an initial inventive concept of a wear protection device for machine components made of a metallic base material, in particular in the form of a coating applied to the components of large two-stroke diesel engines, which consists of at least one layer with particles made of ceramic material included in a metallic matrix.

Another inventive concept relates to a method for the production of a wear protection device of this nature.

A wear protection device and a method of the above type are known from DE 103 19 131 A1. The matrix which holds the ceramic particles in this case takes the form of a Ni, Cr. B. Si alloy. The melting point of this material is in a temperature range above 1300 °C and is therefore very high, but certainly higher than the melting point of materials which are normally used as the base material, such as cast iron, etc. The melting point of cast iron is just 1100 °C. As a result of the high melting temperature of the matrix there is a risk that the carbides which generally form the ceramic particles will dissolve or will be converted into different carbide forms of smaller size and with lower hardness, which may have an adverse effect on the desired wear protection and is therefore undesirable. In addition, if the above matrix material is used, the proportion of carbides in the coating is extremely limited. In the conventional arrangement, a maximum proportion of 50% is normal. Another drawback of the above state of the art is the fact that the temperature of the coating material to be applied to the base material is very high as a result of the high melting temperature of the matrix material so that the base material may be damaged or the base material may suffer undesirable warpage and internal stresses within the base material which in turn can promote the formation of cracks. A great deal of effort is required when applying the coating material and cooling the coating in order to prevent this.

On the basis of this, therefore, the aim of this invention is to improve the wear protection device whilst preventing the drawbacks mentioned above so that not only is high load capacity provided but also the negative effects on the basis material are prevented. Another aim of this invention is to provide a simple, low cost method for producing the wear protection device which is the centrepiece of this invention.

The part of the task which refers to the wear protection device is solved by this invention by making the matrix from a material whose melting point is lower than the melting point of the base material.

This allows the drawbacks listed above to be reliably prevented. As a result of the comparatively low melting point of the matrix material, not only is it possible to provide a high proportion of carbide, but it is also possible to rule out any risk of the undesirable conversion or dissolution of the existing carbides. The measures taken by the invention therefore result in excellent load capacity. Foreign bodies will find it difficult to penetrate into the coating which results in its providing a long service life. Furthermore it ensures that warping of the base material, as well as cooling stresses and cracking will not occur.

Beneficial versions and expedient developments of the above measures are set out in the sub-claims. For example, the matrix may preferably be made of a nickel alloy whose other alloy components at least contain phosphorus (P). By adding phosphorus (P) the melting temperature of nickel (Ni) can be reduced from around 1400 °C to approx. 850 °C and therefore well below the melting temperature of cast iron or other materials which are normally used as base materials. The presence of silicon (Si) together with phosphorus (P) allows this benefit to be increased even further.

A composition of the matrix material perfected by testing is beneficially made of 1 – 15% v/v, ideally 3.65% v/v of P, 1 – 6% v/v, ideally 2.15% v/v of Si and the remainder of Ni.

The closer the ceramic particles are located to each other, the fewer possibilities for attack are offered to foreign bodies. Expediently the coating material therefore consists predominantly of ceramic particles. A beneficial volume ratio of ceramic to the matrix of at least 60 to 40 or a weight ratio of at least 75 to 25 is proposed.

This benefit is reinforced by means of the fact that ceramic particles of different sizes are used wherein the smaller particles can fill the cavities between the larger particles. Expediently the ceramic particles may therefore be spherical in shape with diameters of between 30  $\mu$  and 400  $\mu$  and ideally have diameters between 40  $\mu$  and 160  $\mu$ . Their hardness values are ideally around 3000 HV.

Another beneficial measure may be that the coating consists of several layers with the bottom and top layers having comparatively few or no ceramic particles. A high overall coating thickness can be achieved by simple means using several layers. The ceramic-free coatings may ideally form a thin lower binding coating which helps the bond to the base material and a top cover coating which facilitates retrospective machining.

As a result of the low melting temperature of the matrix material the coating ideally takes the form of a sintering blank which is sintered to the base material.

The aim relating to the method of production is solved by the invention by heating the base material at least over the area to be coated up to a maximum temperature of just below the melting point of the base material and that at the same time or directly after this heating process a material based on the matrix and the ceramic material mix containing the ceramic particles are applied to the heated surface of the base material and sintered on to it using the heat added to the base material.

The low melting point of the matrix material allows the added heat to be used beneficially for sintering the coating directly to the base material. The coating material can therefore be beneficially added to the base material in a solid aggregate state which makes the whole process particularly straightforward.

Beneficial versions and expedient developments of the above measures are set out in the sub-claims. For example, the quantity of the applied material mix may be such that the heat added to the base material is sufficient to melt the matrix material contained in the material mix. This results in a reliable sintering process.

It is of benefit for the first sintering process to be followed by at least one more heating process. This beneficially leads to the strengthening of the areas close to the surface and produces a smooth surface.

The material mix can expediently be applied to the base material in powder form. This allows the application process to be very simple in design.

In a further development of the above measures, the surface to be coated may be exposed to shielding gas at least during the sintering process. This will prevent oxidation.

Another expedient measure could be that the material mix to be applied to the base material is preheated before and/or during the application process. This will accelerate the sintering process.

The expedient versions and beneficial developments of the above measures are set out in the other sub-claims and in the specimen description below on the basis of the drawing.

The following drawing shows the following:

- Figure 1 shows a section through a component to which a wear protection coating has been applied
- Figure 2 shows a section through the wear protection coating in operating condition on a scale which has been increased compared to Figure 1, and
- Figures 3 - 5 show several process stages for the production of a wear protection coating on a piston ring groove.

The invention may be used wherever there is a need to reduce or prevent wear on components which are at risk of wearing. The main area of application for the invention include the support surfaces of piston ring grooves, the bearing surfaces of piston rings, cylinder bushes, pistons, cross-head guides and the like in large engines, in particular large two-stroke diesel engines.

As Figure 1 suggests, components of the above type are made of a metallic base material 1, for example cast iron, and have a coating 2 in the area metallic material 1 which is at risk from wearing. In the example on which Figure 1 is based, the coating 2 comprises several layers. In any event a load bearing layer 3 is created by the central layer which comprises ceramic particles, ideally tungsten carbide (WC), which are included in a matrix comprising metallic material. Below the load bearing layer 3 in the example shown, there is a binding layer 4 and above the load bearing layer 3 there is a top layer 5. The binding layer 4 is designed to produce a good bond between the coating 2 and the base material 1. The top layer 5 is designed to facilitate the retrospective machining of the coating 2.

After the top layer 5 has been removed, in other words in normal operating state, the load bearing layer 3, as shown in Figure 2, is exposed and forms an outside of the component concerned which is exposed to wearing. As mentioned above, the load bearing layer 3 comprises ceramic particles 6 which are included in a metallic matrix 7. The ceramic particles 6 are expediently spherical in shape with their diameter being in the range from  $30\ \mu$  to  $400\ \mu$ . The preferred diameter range is between  $40\ \mu$  and  $160\ \mu$ . This means that smaller ceramic particles 6 can be positioned between larger ceramic particles 6 and Figure 2 shows. This allows the load bearing layer 3 to have a high ceramic content. This may be predominantly made up of ceramic particles. A volume ratio of ceramic particles 6 to matrix 7 of at least 60 to 40 is expedient in this respect. If the materials yet to be described are used, this results in a weight ration of at least 75 to 25.

Foreign bodies 8 indicated in Figure 2, such as combustion residues, material wear, etc. which may have sharp edges and are pressed against the surface which is subject to wear with a force  $F$  and are moved against the latter at a velocity  $v$ , will have very little opportunity to penetrate into this surface since both the large ceramic particles 6 and the accumulations of small ceramic particles 6 will repel the foreign bodies 8, as shown in Figure 2.

As mentioned above, the ceramic particles 6 are preferably made of WC and have a hardness value within a range of at least 3000 HV. The material which forms the matrix 7 is expediently made of a nickel alloy, which in addition to nickel (Ni) also at least contains phosphorus (P). In addition, it may also be a good idea to include silicium (Si). The melting temperature of Ni can be reduced from around  $1400^\circ\text{C}$  to approx.  $850^\circ\text{C}$  by means of P or P in combination with Si, taking it well below the melting temperature of the base material 1, which for cast iron, for example, is around  $1100^\circ\text{C}$ .

Materials which contain 1 – 15% v/v of P, 1 – 6% v/v of Si and the remainder Ni are ideal for forming the matrix 7. Tests have verified that particularly good results can be achieved using a content of 3.65% v/v of P, 2.15% v/v Si and the remainder Ni.

In the area of the load bearing layer 3 there is an approximately even concentration of ceramic particles 6. This concentration falls towards the top and bottom of the coating 2. Expediently the binding layer 4 and the top layer 5 will only be made up of matrix material without ceramic inclusions. It would also be conceivable, of course, to use another suitable metal instead of the matrix material to form the binding layer 4 and/or top layer 5.

The coating 2 expediently takes the form of a sintering blank which is sintered on to the base material 1. For this purpose the base material 1 is heated up to just below the melting point of the base material 1 in the area of the surface which is to be coated. If cast iron is used as the base material 1, the material may be heated up to a maximum of approximately 1050 °C. Immediately after this heating process or at the same time, the material which forms the coating 2 must be applied to the base material 1. This may be a powder mix which contains the matrix material and the ceramic particles in the required concentration.

The powder material may be applied by mechanical or pneumatic means. It would also be conceivable, however, to use a sintering process to form a wire, a strip or other shaped parts to suit the configuration of the surface to be coated using a powdery material mix which contains the matrix material and the ceramic particles in the required concentration and then to place this part or these parts on to the surface to be coated wherein a certain amount of fixing is possible by means of soldering, etc. A binding agent such as potassium water glass may be used to fix the powdery material mix and this agent will then disappear during the sintering process.

In any case it is important that the applied quantity of the material mix does not exceed the quantity whose matrix content can be melted by the heat supplied during the heating process. Compliance with this condition will ensure that a reliable sintering process is achieved.

The heat may also be supplied in several stages. For example an initial sintering process can be carried out on the applied material by means of an initial heating process. In a subsequent additional heating process it is then possible to carry out a final sintering process. In the event of the coating having a comparatively high thickness, the processes of heating and material addition must be carried out several times in sequence. Identical or different material compositions may be used for this purpose. The material addition and heating can be expediently carried out in successive processes in crossing directions.

The material composition is adjusted to suit the relevant function. For a multi-layer coating of the type shown in Figure 2, multi-layer coatings are required in any case wherein only the binding layer 4 is applied in the first stage and the load bearing layer 3 and finally the top layer 5 are then applied in at least one or more additional stages. It is also conceivable to carry out a final heating process to smooth the surface.

The heating process may take place by different means wherein the selected equipment can be adjusted to suit the conditions of the case concerned. For example, the use of an induction coil is conceivable for heating areas that offer poor access. This may be particularly expedient, for example, in the case of piston ring grooves. It would also be conceivable to heat the component for coating in a furnace or using a gas flame or a laser beam, etc. In the event of its being heated in a furnace, the material mix which makes up the coating 2 can be applied before the component is placed in the furnace or immediately after the component is taken out of the furnace. Heat sources

which produce localised heating, such as a gas flame, a laser beam or an induction coil, are expediently moved relative to the component they are heating at a specific velocity. The supply of the coating material can be carried out either following the moving heat area, next to it or actually inside it. If a laser beam is used the coating material is expediently added on to the actual hot area created by the laser beam.

It is also possible to preheat the material mix which makes up the coating. In this case the heat added to the base material 1 to create a sintering effect is reduced yet a good sintering effect is nevertheless produced. In many cases the material mix being applied will be so hot that the matrix material will already be molten so that the required heating of the base material can be drastically reduced or may even be completely unnecessary.

Figure 3 – 5 are based on the coating of a load bearing surface of a piston ring groove 9 on a piston 10 for a large two-stroke diesel engine. The top section of the piston 10, which features several piston ring grooves located one after the other, is generally made of cast iron. To heat the base material which consists of cast iron, an induction coil 11 is used in the example shown as can be seen in Figure 3. This induction coil is positioned above the surface which is to be coated in the piston ring groove 9. It would also be conceivable to use several induction coils 11 to surround the entire circumference of the piston ring groove 9. Generally, however, a single induction coil 11 extending over a section of the circumference of the groove is sufficient as it can be moved around the circumference. Naturally it would also be conceivable to make the induction coil 11 stationary and instead to rotate the piston 10. The important thing is that there is a relative movement so that the induction coil can heat a local area and this process can be continued around the entire circumference of the surface which is to be heated.

The material mix which forms the coating is added in this case in powder form. A blowing nozzle 12 is provided for this purpose using which the powdery material mix is either fed straight to the area which is heated by the induction coil or in the area which the induction coil has heated recently.

The area in which the material mix is added is expediently exposed to shielding gas. A shielding gas may be used for this purpose to provide the pneumatic transport system for the material mix. In the example in the figure the blowing nozzle 12 is fitted with additional peripheral shielding gas nozzles 13 for this purpose.

The process described above is repeated several times to produce the multi-layer coating 2 on which Figure 1 is based, wherein only the powder which contains the matrix material is used to produce the binding layer 4 and the top layer 5. If the load bearing layer 3 has a thickness which cannot be produced in a single cycle, several processes of the type described above may also be carried out to produce the load bearing layer 3. In many cases it may be expedient to carry out a further heating process without applying any further material after the application of the entire material mix which makes up the load bearing layer 3. This is demonstrated in Figure 4. In this figure, the induction coil 11 is activated. The nozzles 13 to supply the shielding gas may also be activated to prevent oxidation. This additional heating process provides the benefit of ensuring a reliable sintering process even for the areas close to the surface and also smoothes the surface of the coating.

After completing the coating process the applied coating 2, as indicated in Figure 5, may be covered by a cover element 14 formed by a metal plate, etc. for the cooling process so as to prevent oxidation during the cooling process. The cover element 14 may expediently be treated with a separating agent before it comes into contact with the surface of the coating 2 so that after the cooling process has been completed it can be removed easily.

In the example shown, the coating 2 is inserted into a pocket-shaped recess 16 which extends from an internal radial lip 16 on the piston ring groove 9 to the external radial edge of the piston ring groove 9, and this recess is open at its external radial side. So as to be able to apply a reliable coating even in the area of the external radial area, the recess 16 is closed during the production of the coating 2 by means of a surrounding closure strip 17 which is removed after the coating 2 has been produced. The closure strip 17 is therefore treated with a separating agent on its inside. To prevent any contamination of the lip 15 and the areas of the piston ring groove 9 behind it during the coating process, a cover element 18 is positioned in the area shown and this is located in the internal radial area of the piston ring groove 9 during the coating process. Treatment with a separating agent is once again expedient in this case.

## Claims

1. Wear protection device for machine components made of a metallic base material (1), in particular components of large two-stroke diesel engines, which takes the form of a coating (2) which can be applied to the base material and consists of at least one layer (3), and contains a metallic matrix (7) consisting of a nickel alloy which has a lower melting point than the base material and has at least phosphorus as an alloy element and also contains ceramic material particles (6) and is available in such a form that a powder containing the material which forms the coating is applied to the surface of the base material by means of a thermal coating process wherein the ceramic particles (6) are spherical in shape and have a diameter of 40 to 160  $\mu$  and a hardness of 3000 HV.
2. Wear protection device as described in claim 1, **characterised by the fact that** the nickel alloy which forms the matrix (7) has a melting point which is considerably lower than the melting point of the base material (1).
3. Wear protection device as described in claim 2, **characterised by the fact that** the nickel alloy which forms the matrix (7) has a melting point which is at least 200 °C lower than the melting point of cast iron.
4. Wear protection device as described in one of claims 1 to 3, **characterised by the fact that** the matrix (7) contains 1 – 15% v/v, of P, 1 – 6% v/v of Si and the remainder of Ni.
5. Wear protection device as described in claim 4, **characterised by the fact that** the matrix (7) contains 3.65% v/v of P, 2.15% v/v of Si and the remainder of Ni.
6. Wear protection device as described in one of the above claims, **characterised by the fact that** the volume ratio of ceramic particles (6) to matrix (7) is at least 60 to 40 and/or the weight ratio is at least 73 to 25.
7. Wear protection device as described in one of the above claims, **characterised by the fact that** the ceramic particles (6) consist least in part of WC.
8. Wear protection device as described in one of the above claims, **characterised by the fact that** the coating (2) has a multi-layer construction with the layers at the bottom and top (4 and 5) contain comparatively low quantities of ceramic particles (6) or none at all.
9. Wear protection device as described in claim 8, **characterised by the fact that** the bottom layer (4) and the top layer (5) are made at least in part and preferably in full of the material on which the matrix (7) is based.
10. Wear protection device as described in one of the above claims, **characterised by the fact that** the coating (2) takes the form of a sintering blank which is sintered to the base material (1).
11. Wear protection device as described in one of the above claims, **characterised by the fact that** the coating (2) is applied to a component which is made of a temperature-sensitive material, preferably cast iron, such as piston rings, piston ring grooves, cylinder bushes, pistons and guides of large two-stroke diesel engines.

12. Method for the production of a wear protection device for machine components made of a metallic base material (1), in particular components of large two-stroke diesel engines, which takes the form of a coating (2) which can be applied to the base material (1), the coating is made of a low melting point nickel alloy with a metallic matrix (7) with a lower melting point than the base material (1) and particles (6) included in it made of a ceramic material, in particular as described in one of the previous claims, **characterised by the fact that** the base material (1) is heated locally in the area to be coated to a temperature just below the melting point of the base material (1) and that at the same time or immediately afterwards a material mix containing the material based on the matrix (7) and the ceramic particles (6) is applied in powder form to the locally heated surface of the base material (1) and is sintered on to it using the heat locally added to the base material (1) wherein the quantity of the material mix applied is such that the heat added to the base material (1) is sufficient to melt the matrix material included in the applied material mix and wherein during the heating of the base material (1) and the addition of the powder mix which contains the coating material, a relative movement parallel to the surface takes place between the heat source used to provide localised heating and the surface to be coated and wherein the powder mix containing the material on which the matrix (7) is based and the ceramic particles is placed in an area which directly follows the heated area or in the heated area itself.
13. Method described in claim 12, **characterised by the fact that** after an initial sintering process at least one heating process takes place without adding any further material.
14. Method described in one of claims 12 or 13, **characterised by the fact that** the surface to be coated is exposed to shielding gas at least during the sintering process.
15. Method described in one of claims 12 to 14, **characterised by the fact that** the material mix applied to the base material (1) is preheated before and/or during the application process.
16. Method described in one of claims 12 to 15, **characterised by the fact that** the coating (2) is applied in several layers (4, 3, 5) in succession.
17. Method described in claim 16, **characterised by the fact that** the successive layers (4, 3, 5) have different material compositions.
18. Method described in claim 17, **characterised by the fact that** a bottom binding layer (4) and/or a top layer (5) is/are used and these are predominantly or completely free of ceramic particles and are ideally made of the material on which the matrix (7) is based.