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**Method for producing machine parts that are provided  
with at least one slide face**

5 The invention relates to a method in accordance with  
the preamble of claim 1.

A method of this kind is already known. JP 01 1163 26A  
presents a brake disc which is coated in the region of  
10 the slide faces. In order to form the coating, a  
powder mixture is used that contains all the coating  
materials in powder form, here a proportion consisting  
of an aluminium bronze, a proportion consisting of a  
chromium alloy and a proportion consisting of carbides  
15 and/or oxides etc., and is applied to the base material  
using the thermo-spraying method.

US-A 3941 903 covers a method for producing a wear-  
resistant coating of a bearing portion. In order to  
20 form the coating, here as well a powder mixture is used  
that contains all the coating materials in powder form,  
here a proportion consisting of aluminium bronze and a  
proportion formed by oxides, carbides or the like, and  
is applied to the carrier material using the plasma-  
25 spraying method, by flame-spraying or by detonation.

WO 98 25 017 A belonging to the applicant covers a  
cylinder element, such as a cylinder liner, a piston,  
piston rings etc. of diesel engines which in the region  
30 of their slide face are provided with a coating that is  
sprayed on using the thermo-spraying method and  
consists of aluminium bronze in which hard particles in  
the form of oxides, carbides and the like can be  
included. It is not possible to infer from the WO-A  
35 mentioned how a mixture of the materials which are

melted during the spraying process and the materials which are not melted during the spraying process is to be brought about.

5     Basing considerations on this, the object of the present invention is to improve a method of the kind mentioned at the beginning in such a way that it is possible to produce the coating in a simple and inexpensive manner, which coating, in relation to the  
10    other coating materials that melt during the spraying process, contains comparatively hard inclusions in the form of a powder that is not melted during the spraying process.

15    This object is achieved by means of the characterising part of claim 1.

      The use of a hollow wire, the hollow space of which contains a powder which forms the inclusions,  
20    guarantees that when the hollow wire melts off this powder automatically reaches the melt and therefore the spray jet and is thus sprayed on together with the other molten materials. Advantageously, additional outlay on mixing is not then required. A further  
25    advantage can be seen in the fact that reliable dosage and uniform distribution of the inclusions can be achieved in a simple manner.

      Advantageous developments are specified in the  
30    subclaims.

      A few examples are explained in the following with reference to the drawing.

35    In the drawing which is described in the following:

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Figure 1 shows an example for application in the form of a detail portion of a cylinder of a large engine;

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Figure 2 shows a diagrammatic representation of an apparatus for carrying out the method in accordance with the invention; and

10 Figure 3 shows a development of the apparatus in accordance with Figure 2.

The main field of application of the present invention is that of large engines, such as, for example, large two-stroke diesel engines used as ships' drives, and in that case in particular the parts which are provided with running faces, such as the cylinder liners, pistons, piston rings etc.. The example taken as a basis for Figure 1 presents a cylinder liner 1 with a piston 2 that is arranged therein and is provided with piston rings 3. These are provided with a coating 4, which is to prolong the service life, in the region of their running face on the peripheral side. Of course, it would also be possible to coat as well, at the same time or alternatively, the running face of the cylinder liner 1 and/or the piston skirt etc..

The apparatus taken as a basis for Figure 2 contains a receiving device, here in the form of a platform 6, to receive the base material that is to be coated, here a piston ring 3. A spraying head 7 is provided at a distance above the platform 6. This spraying head 7 has a tubular housing 9 that is conically narrowed at its front end facing the platform and is provided with an outlet opening 8. The housing 9 can be provided

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with a handle, which is not shown here in detail, for manual operation or can be accommodated in a displaceable manner on a frame that is associated with the platform 6. Of course, it would also be possible  
5 to arrange the spraying head 7 in a stationary manner and provide the platform 6 with a displaceable workpiece receiver.

Associated with the outlet opening 8 there are two  
10 wire-feed lines 10, 11 which end at a short distance from the outlet opening 8. A wire 14, 15 which can be drawn off from an associated drum 12, 13 can be supplied to the wire-feed lines 10, 11 respectively. The advance of the wire is effected by means of a  
15 respective advancing device 16.

The drums 12, 13 and thus also the wires 14, 15 that are drawn off therefrom are connected to different poles of a current source 17. The current intensity of  
20 the current source 17 is rated so that between the ends of the wires emerging from the wire-feed lines 10, 11 an electric arc 18 is produced that results in the front ends of the wires 14, 15 melting off even in the case of different melting temperatures of the materials  
25 that are taken as a basis for the wires 14 and 15 respectively. The melting temperatures of the materials that are taken as a basis for the wires 14 and 15 respectively can therefore be different. As a rule, the melting temperature of aluminium bronze is  
30 lower than the melting temperature of chromium alloys.

Since the wires 14, 15 are advanced continuously, a melt is produced constantly. This is blown away in the form of small droplets by means of a gas jet that is

directed onto the platform 6. The spray jet 5 thus formed, upon striking the base material that is to be coated, forms the coating 4 which then contains not only the material of the wire 14 but also the material of the wire 15. In order to produce the gas jet that has been mentioned, a jet pipe 24 is provided that ends in the form of a nozzle above the ends of the wires 14, 15 which are melting off and is connected to a suitable compressed-gas source which is not shown.

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In the example in accordance with Figure 2 only one spraying head 7 is provided for two wires, between which the arc 18 is ignited. It would, however, also be possible for each wire to have its own spraying head associated with it, with it being possible to ignite an arc in each case between two spraying-head portions, for example between a wire-outlet nozzle and a tubular jacket surrounding the latter, which arc can be expelled by a gas jet of a gas that is supplied from the tubular jacket.

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In simple cases it suffices if the coating 4 is in one single layer, since in many cases the desired properties can already be attained by means of a suitable material mix. Such a coating can advantageously be applied in one operation. A multi-layer, for example a double-layer, configuration of the coating 4 is, however, also possible and often advantageous.

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In the case of a multi-layer coating, advantageously it can be possible to provide a first, comparatively soft layer and on top of that a comparatively hard layer. The first layer in this connection results in good bonding of the outer layer on the base material. A

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material mix that results in very great hardness and which would be subject to a high risk of chipping without the softer first layer can therefore be used for the outer layer. The outer layer can then easily  
5 be 3 to 5 times harder than the base material, this resulting in good stability. The material mix for the first layer is advantageously chosen in such a way as to give a hardness lying between the hardness of the base material and the hardness of the outer layer and  
10 correspondingly small jumps in hardness. The corrosion resistance can also be influenced by appropriate choice of material.

In the case of a multi-layer coating, advantageously  
15 comparatively great overall thickness of the coating can be achieved. Such a coating can be compressed a little after the application process, this advantageously resulting in an increase in the hardness. The compression that is desired in this  
20 respect can be achieved by means of a treatment process, for example a grinding process, or results automatically during operation, in particular during the run-in phase. The compression which has been  
25 mentioned is also possible in the case of a single-layer coating, though to a lesser extent in view of the lesser thickness.

The coating 4 in each case consists of an aggregation of aluminium bronze and at least one further material  
30 that is not alloyed with the aluminium bronze applied in the form of a melt. In any case, hard inclusions which do not melt during the spraying process are provided in this connection. In addition, at least one further material that melts but does not enter into an  
35 alloy with the aluminium bronze, for example a chromium

alloy which is harder than the aluminium bronze, can be provided. In the case of a multi-layer coating the individual layers can in each case consist of the same material mix or different material mixes. The  
5 aluminium bronze then acts practically as a matrix which takes up the further material or the further materials.

10 In the example shown, the wire 14 is to consist of an aluminium bronze. The other wire 15 can contain the further material that is used to form the coating 4 and does not enter into an alloy with the aluminium bronze.

As a result of an aggregation of materials that are not alloyed together, the qualities of the aluminium  
15 bronze forming the matrix material can be improved in any desired direction. Aluminium bronze as a rule has good run-in properties. As a result of additional use of a further material that melts upon application and which is harder than aluminium bronze, for example a  
20 chromium alloy, in addition comparatively great hardness and thus good wear-resistance and corrosion-resistance can be achieved. The corrosion-resistance can also be influenced by suitable choice of the material. As a result of the even harder inclusions  
25 already mentioned above, the effects that have been mentioned are further intensified.

It is possible to influence the properties of the matrix formed by the aluminium bronze by means of the  
30 choice of the alloy constituents of the aluminium bronze. Thus an aluminium bronze having 7% to 12%, preferably 9%, Al, 0.5% to 2%, preferably 1%, Fe and the remainder as Cu forms a comparatively soft matrix.

If a comparatively hard matrix is desired, an  
35 aluminium bronze with 14% Al, 2% to 8%, preferably 4%,

Fe, 0.5% to 5%, preferably 2%, Mn and the remainder as Cu can be used.

5 An inexpensive chromium alloy can contain 10% to 15%, preferably 13%, Cr, 0.2% to 0.5%, preferably 0.35%, C and the remainder as Fe. In order to increase the hardness the proportions can be changed and further elements can be added or exchanged. Thus with a chromium alloy having 25% to 35%, preferably 28%, Cr,  
10 2% to 7%, preferably 5%, C, 0.5% to 3%, preferably 1%, Mn and the remainder as Fe greater hardness results than with the above-mentioned chromium alloy. A further increase can be achieved with a chromium alloy with 25% to 35%, preferably 28%, Cr, 2% Mn, 3.7% B,  
15 1.7% Si and the remainder as Fe, with it being possible to vary the proportions of Mn, B and Si by  $\pm 1\%$ . Particularly great hardness is produced with a chromium alloy having 40% to 50% Cr, 6% to 12% Mo, 2% to 5% C, 2% to 5% Fe and the remainder as Ni. In this  
20 connection, preferably 45% Cr, 9% Mo, 3.5% C, 3.5% Fe and the remainder as Ni can be provided.

Each of the above-mentioned chromium alloys can be combined with each of the aluminium bronzes further  
25 mentioned above. In this connection given a combination with the harder aluminium bronze greater hardness of the coating also results and vice versa. In this way favourable coatings can be produced for each individual case. Tests have shown that a  
30 combination of one of the aluminium bronzes mentioned above with the first chromium alloy mentioned above having respectively preferably 13% Cr, 0.2% to 0.5% C and the remainder as Fe results in a particularly good piston-skirt coating, with it being possible to  
35 influence the hardness thereof by the use of the one or

other aluminium bronze. A combination of the one or other aluminium bronze of the kind mentioned above with the second or third chromium alloy having respectively preferably 28% Cr, 5% C, 1% Mn and the remainder as Fe or 28% Cr, 2% Mn, 3.7% B, 1.7% Si and the remainder as Fe results in a coating that is particularly well suited for piston rings.

The combination of the one or other aluminium bronze of the kind mentioned above with a chromium alloy having 40% to 50% Cr, 6% to 12% Mo, 2% to 5% C, 2% to 5% Fe and the remainder as Ni or preferably 45% Cr, 9% Mo, 3.5% C, 3.5% Fe and the remainder as Ni results in a particularly good cylinder-liner coating, in which case in turn, as in the other cases as well, the overall hardness can be reduced by the use of the aluminium bronze having respectively preferably 9% Al, 1% Fe and the remainder as Cu and can be raised by the use of the aluminium bronze having respectively preferably 14% Al, 4% Fe, 2% Mn and the remainder as Cu.

Further possibilities for influencing the properties of the coating lie in the choice of the blow-out gas used. In simple cases air can be used for this. It would, however, also be possible to use N<sub>2</sub>, argon, helium or hydrogen or combinations of these gases. When air is used, the formation of oxides is promoted, this improving the wear-resistance. When N<sub>2</sub> is used, fewer oxides develop with the expectation of comparatively great hardness. When argon and/or helium and/or hydrogen is/are used, comparatively high temperatures can be applied with the expectation of a particularly high level of compactness of the coating that is produced.

In connection with the combination of one of the above-mentioned aluminium bronzes with the chromium alloy having respectively preferably 13% Cr, 0.2% to 0.5% C and the remainder as Fe, the use of air as a blow-out gas has proved to be particularly advantageous. In connection with the chromium alloy having respectively preferably 28% Cr, 5% C, 1% Mn and the remainder as Fe, the use of N<sub>2</sub> as a blow-out gas has proved to be particularly advantageous. In connection with the chromium alloy having respectively preferably 28% Cr, 2% Mn, 3.7% B, 1.7% Si and the remainder as Fe, experience shows that argon is to be preferred as a blow-out gas. In connection with the chromium alloy having respectively preferably 45% Cr, 9% Mo, 3.5% C, 3.5% Fe and the remainder as Ni, helium or a combination of helium and/or argon and/or N<sub>2</sub> is/are to be preferred as a blow-out gas.

Further variational possibilities lie in the choice of the speed of advance of the wires 14, 15 and/or the thickness of the wires 14, 15. These variables are advantageously chosen in such a way that the proportion of the aluminium bronze in the coating amounts to at least 50%, advantageously to over 50%, so that a spacious matrix results for the further material that is still to be added.

What has been stated above in general with respect to the coating of course in the case of a multi-layer coating also applies to the individual layers.

In Figure 3 the front ends of two wires 19 and 20 that have been melted off are shown, with the one wire 19 here being formed as a solid wire that consists of an aluminium bronze of the above-mentioned kind. The

other wire 20 is formed as a hollow wire which consists of a chromium alloy of the above-mentioned kind, preferably of the chromium alloy having 40% to 50% Cr, 6% to 12% Mo, 2% to 5% C, 2% to 5% Fe and the remainder as Ni, which has the greatest hardness of the chromium alloys mentioned. The hollow space of the hollow wire 20 contains a filling 21 which is formed by carbides or oxides present in powder form, for example  $W_2C$ ,  $Cr_3C_2$ ,  $Ni_3C$  or  $CrO$ . This powder is released when the wires 19, 20 melt off without itself melting and is carried away with the droplets of the molten materials by the gas jet that is supplied.

The carbides or oxides that are present in powder form are accordingly sprayed onto the base material, here the cylinder liner 1, together with the molten materials in order to form a coating 22 and thereby form grains 23 that are included in the coating 22 and are harder than the other coating materials in the form of the aluminium bronze and the chromium alloy. During the operation of the coated machine part, as soon as the carbides or oxides that are present in powder form and have been sprayed on together with the molten materials forming the wire 19 and the hollow wire 20 are exposed, these result in a certain honing effect by means of which run-in residues found on the surface of the counter-workpiece after the run-in phase are removed. At the same time, oil pockets which guarantee reliable lubrication are formed.

Whilst some preferred exemplary embodiments of the invention have been explained in detail above, no limitation is to be linked therewith. On the contrary, a series of possibilities are available to the person skilled in the art in order to adapt the general idea

of the solution to the circumstances of the individual case. It would, for example, be possible for the coating or a layer of the coating to be formed only by aluminium bronze and inclusions in the form of the grains 23 mentioned above. In order to produce such a coating, a hollow wire consisting of the desired aluminium bronze and filled with the powder material provided for the formation of the inclusions could be used, for example.

### Claims

1. Method for producing machine parts that are provided with at least one slide face, in particular  
5 piston rings (3) and/or pistons (2) and/or cylinder liners (1) of engines, preferably large two-stroke diesel engines, which in the region of their slide face are provided with a coating (4 and 22 respectively) that is applied to the base material using the thermo-  
10 spraying method and is formed by an aggregation of aluminium bronze and at least one further material that is not alloyed therewith, with the coating (22) containing in relation to the other coating materials comparatively hard inclusions (23) which in the form of  
15 a powder that is not melted during the spraying process are sprayed on with the other coating materials that are melted for spraying purposes, **characterized in that** in order to form the spray jet at least one wire (20) that is formed as a hollow wire and whose hollow space  
20 contains the powder that forms the inclusions (23) is melted off.

2. Method according to claim 1, **characterized in that** the coating (4, 22) contains in addition to aluminium  
25 bronze a further material that melts during the spraying process and is harder than the aluminium bronze that is used.

3. Method according to claim 2, **characterized in that**  
30 the further material that melts during the spraying process is a chromium alloy.

4. Method according to claim 3, **characterized in that** the chromium alloy contains at least the elements Cr, C  
35 and Fe.

5. Method according to one of the preceding claims, **characterized in that** the chromium alloy contains 10% to 15% Cr, 0.2% to 0.5% C and the remainder as Fe.
- 5 6. Method according to claim 5, **characterized in that** the chromium alloy contains 13% Cr, 0.35% C and the remainder as Fe.
- 10 7. Method according to one of the preceding claims 1 to 4, **characterized in that** the chromium alloy contains 25% to 35% Cr, 2% to 7% C, 0.5% to 3% Mn and the remainder as Fe.
- 15 8. Method according to claim 7, **characterized in that** the chromium alloy contains 28% Cr, 5% C, 1% Mn and the remainder as Fe.
- 20 9. Method according to one of the preceding claims 1 to 3, **characterized in that** the chromium alloy contains 25% to 35% Cr, 2% Mn, 3.7% B, 1.7 % Si and the remainder as Fe.
- 25 10. Method according to claim 9, **characterized in that** the Cr portion amounts to 28%.
- 30 11. Method according to one of the preceding claims 1 to 3, **characterized in that** the chromium alloy contains 40% to 50% Cr, 6% to 12% Mo, 2% to 5% C, 2% to 5% Fe and the remainder as Ni.
- 35 12. Method according to claim 11, **characterized in that** the chromium alloy contains 45% Cr, 9% Mo, 3.5% C, 3.5% Fe and the remainder as Ni.

13. Method according to one of the preceding claims,  
**characterized in that** the aluminium bronze contains at  
least the elements Al, Fe and Cu.

5 14. Method according to one of the preceding claims,  
**characterized in that** the aluminium bronze contains 7%  
to 12% Al, 0.5% to 2% Fe and the remainder as Cu.

15 15. Method according to claim 14, **characterized in**  
**that** the aluminium bronze contains 9% Al, 1% Fe and the  
remainder as Cu.

16. Method according to one of the preceding claims 1  
to 13, **characterized in that** the aluminium bronze  
15 contains 13% to 18% Al, 2% to 8% Fe, 0.5% to 5% Mn and  
the remainder as Cu.

17. Method according to claim 16, **characterized in**  
**that** the aluminium bronze contains 14% Al, 4% Fe, 2% Mu  
20 and the remainder as Cu.

18. Method according to one of the preceding claims,  
**characterized in that** the proportion of aluminium  
bronze in the coating amounts to at least 50%.

25 19. Method according to one of the preceding claims,  
**characterized in that** the inclusions (23) which do not  
melt during the spraying process are formed by carbides  
and/or oxides.

30 20. Method according to one of the preceding claims,  
**characterized in that** in order to form a spray jet (5)  
two wires (14, 15; 19, 20) are melted off at a  
predetermined distance from the base material and at  
35 least one gas jet that is directed onto the base

material is applied to them, with one wire (14, 19) being associated at least with the aluminium bronze and one wire (15, 20) being associated at least with a further material.

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21. Method according to one of the preceding claims, **characterized in that** at least one electric arc (18) is generated in order to melt off the wires (14, 15; 19, 20).

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22. Method according to claim 21, **characterized in that** the wires (14, 15; 19, 20) are connected to different poles of a current source (17), with preferably the wire (14, 19) that is associated with the aluminium bronze being connected to the positive pole and the further wire (15, 20) being connected to the negative pole.

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23. Method according to one of the preceding claims 20 to 22, **characterized in that** the diameter of the wire (14, 19) associated with the aluminium bronze is greater than the diameter of the other wire (15, 20).

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24. Method according to one of the preceding claims, **characterized in that** the gas jet that is produced for spraying purposes contains air and/or nitrogen and/or argon and/or helium and/or hydrogen.

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25. Method according to one of the preceding claims, **characterized in that** the coating (4, 22) is sprayed on in multiple layers.

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26. Method according to claim 25, **characterized in that** in the case of a multi-layer coating (4, 22) the outer layer(s) is/are formed so as to be thicker than

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the inner layer.

27. Method according to claim 25 or 26, **characterized in that** in the case of a multi-layer coating (4, 22)  
5 the outer layer(s) is/are formed so as to be harder than the inner layer.

28. Method according to one of the preceding claims 1  
10 to 24, **characterized in that** the coating (4, 22) is sprayed on as a single layer.

29. Method according to one of the preceding claims, **characterized in that** the coating (4, 22) is compacted after having been sprayed on.