PLASMA SPRAYING PROCESS

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ABSTRACT
The application relates to a process for producing a coating by thermal spraying, in particular by plasma spraying, in which a component, in particular a cylinder liner, is internally coated with an alloy, wherein a plasma nozzle, to which a plasma gas and a transporting gas are fed, rotates about a wire and is movable along a longitudinal axis of the bore, such that the bore is coated as seen from the inside all around and in the axial direction of the bore. What is proposed is a variable gas stream or a variable flow rate of the transporting gas and/or of the plasma gas, it being possible for the flow rate to be set over the axial length (x) of the bore to be coated.
PLASMA SPRAYING PROCESS

[0001] The present invention relates to a process for producing a coating by thermal spraying, in particular by plasma spraying, in which a component, in particular a bore of an internal combustion engine, which is produced for example from a light metal, is coated with an alloy, preferably with an iron alloy, wherein a plasma nozzle, to which a plasma gas and a transporting gas are fed, rotates about a wire and is movable along a longitudinal axis of the bore, such that the bore is coated as seen from the inside all around and in the axial direction of the bore.

[0002] It is known from EP 1 967 601 A2 to coat, for example, an aluminum engine block, in particular the cylinder bearing surface thereof, with an iron alloy by carrying out arc wire spraying. In this respect, EP 1 967 601 A2 proposes the use of an iron alloy which contains, inter alia, 5 to 25% by weight chromium. It is essential in the case of EP 1 967 601 A2 that an additional powder, to be precise boron carbide, is additionally fed to the iron melt. The arc wire spraying process of EP 1 967 601 A2 involves what is known as the TWAS process, in which two wires are fed to a spray head in such a manner that the power is transmitted across the wires. If the two wires make contact, an arc which melts the wires is formed by a permanent short circuit. A nozzle from which compressed air or an inert gas such as nitrogen is discharged is located downstream of the nozzle. This gas stream atomizes the molten iron alloy and feeds it together with the molten boron carbide powder to the surface to be coated.

[0003] DE 44 11 296 A1 and DE 44 47 514 A1 are concerned with coatings provided by means of plasma spraying, in which however a metal powder or a filler wire are melted and in which nitrogen is fed to the material mixture by means of metallic nitrogen compounds in order to harden the coating.

[0004] EP 0 858 518 B1 is concerned with a process for producing a sliding surface on a light metal body by thermally spraying a coating made of steel and molybdenum, in which the wearing layer is applied by means of plasma spraying. EP 0 858 518 B1 states, however, that a mixture of steel powder with molybdenum powder is used.

[0005] EP 1 340 834 B1 describes a process for producing a cylinder running surface layer. Here, use is made of a rotating plasma spraying apparatus, and therefore the engine block to be coated can rest during the coating. The proportion of pores can be influenced in a targeted manner depending, for example, on the particle size of the coating powder.

[0006] FR 2 924 365 A1, too, is concerned with the plasma spraying of inner walls, with use likewise being made of an additional spraying powder. The capacity of the pores in the coating should be different, which should be achievable by a way of a change in the plasma spraying parameters, for example the size, the hardness, the speed and the preheating temperature of the metal particles or of the metal powder.

[0007] Present-day internal combustion engines and the engine blocks thereof can be cast from a metal or from a light metal, e.g. aluminum or magnesium, light metal blocks in particular having an iron or metal layer on the cylinder bores thereof. The metal layer can be sprayed on by thermal processes. The processes mentioned above are known as thermal spraying processes.

[0008] The relevant prior art for the present invention includes what is known as the PTWA (Plasma Transferred Wire Arc) internal coating process. In this process, bores (cylinder bores) can be coated from the inside with a wire-like spraying additive by virtue of the fact that a nozzle rotates about the wire in the interior of the bore and is moved along the axis of the bore. The inner wall is thus coated completely as seen all around and in the axial direction. It is essential in the PTWA process that no metal powder is sprayed, but instead a homogeneous wire is melted and the molten droplets thereof are transported to the inner wall to be coated, where they impinge, such that the coating forms. Here, only a single wire-like spraying additive is thus supplied. The plasma impinges on the preheated, wire-like spraying additive. The plasma gas is usually an argon-hydrogen mixture. In the PTWA process, air or compressed air is used as the transporting gas or atomizer gas. The layers which are produced by this process are distinguished by a low porosity. The PTWA internal coating process has proven suitable to date for the internal coating of cylinder bores, in particular light metal blocks.

[0009] The coating customarily has pores, which reduce the friction between the piston rings and the cylinder running surface since lubricant can accumulate in the pores. EP 1 340 834 B1, EP 0 858 518 B1 and FR 2 924 365 A1 deal with influencing the appearance of pores in the coating.

[0010] On the basis of the fact that the pores in the coating are also decisive for the frictional resistances between the piston rings and the cylinder running surface, the invention is based on the object of specifying a process of the type mentioned in the introduction which makes it possible to produce a coating which is improved in this respect.

[0011] According to the invention, the object is achieved by a process having the features of claim 1. Further particularly advantageous refinements of the invention are disclosed in the subclaims.

[0012] It is pointed out that the features specified individually in the following description may be combined with one another in any desired technically meaningful way and disclose further refinements of the invention.

[0013] The invention proposes a process for producing a coating by thermal spraying, in particular by plasma spraying, preferably by means of the PTWA internal coating process, in which a component, in particular a bore of an internal combustion engine, which is produced for example from a light metal, is coated with an alloy, preferably with an iron alloy, wherein a plasma nozzle, to which a plasma gas and a transporting gas are fed, rotates about a wire and is movable along a longitudinal axis of the bore, such that the bore is coated as seen from the inside all around and in the axial direction of the bore, in which process a variable gas stream and/or a variable flow rate of the plasma gas and/or of the transporting gas can be set over the axial length of the bore to be coated.

[0014] Expediently, it has been identified with the invention that the gas stream, be it the plasma gas stream and/or the transporting gas stream, can have different magnitudes during the coating operation at different positions along the longitudinal axis of the inner wall to be coated. If the flow rate of the gases is variable over the axial length of the bore, different pore proportions can be established in the coating depending on the flow rate value. With the invention, it has advantageously been identified that a low gas flow rate produces a high pore proportion in the coating and a relatively high gas flow rate produces a low pore proportion in the coating. The internal coating can of course also be subsequently machined, for example honed, and/or lapped, in order to name just a few subsequent machining processes merely by way of example.
[0015] Pistons are moved to and fro in a known manner in the cylinder bore. The piston rings are in contact with the cylinder running surface, i.e., with the coating. Particularly in the region of the top dead center of the cylinder bore, there should be little friction (reversal of the direction of the piston). It is therefore expediently provided that the gas flow rate in the region of the top dead center has a low value, so that a high pore proportion forms. In the bottom dead center region, too, such a high pore proportion can be provided in the coating. In a central region, but also above the top dead center region, by contrast, the pore proportion can be reduced, and therefore a relatively high flow rate can be set.

[0016] As has already been described, the plasma spraying apparatus is movable to and fro in the axial direction along the bore. Thus, together with the rotation, an extensive internal coating can be produced. Here, the spraying procedure can be started at a top region of the bore. Here, the coating can have a small pore proportion, and therefore the flow rate of the gas can be set to a high value of e.g. 1100 l/min.

[0017] If the plasma spraying apparatus is moved along the longitudinal axis toward the opposite end of the bore, and reaches the top dead center region, it is expediently provided to reduce the flow rate and to change it to a low value of e.g. 450 l/min, in order to produce a high pore proportion in the coating. A relatively low flow rate causes a relatively low impact energy of the molten wire droplets on the inner wall.

[0018] If the plasma spraying apparatus leaves the top dead center region toward the opposite end of the bore, it is possible in turn for a flow rate with a high value of e.g. 1100 l/min to be set, such that a coating with a low pore proportion is similarly achievable. The remainder of the inner wall of the bore can then be coated at this high flow value.

[0019] As has already been mentioned, it is possible to reduce the flow rate in a bottom dead center region to a low value of 450 l/min, such that a high pore proportion is present in the coating. However, this is advantageous particularly in the top dead center region, with a coating having a low pore proportion being sufficient in the bottom dead center region.

[0020] It is thus expedient in the invention that coating regions with different pore proportions are achievable over the axial length of the bore to be coated, the top dead center region in particular having a particularly high pore proportion. This is achieved by way of the variable flow rate of the gas, it being possible for a low flow rate of e.g. 450 l/min to be set in the top dead center region.

[0021] It is advantageous if the flow rate of the transporting gas can be set variably. It is also conceivable that the flow rate of the plasma gas together with the transporting gas or per se can be set variably.

[0022] The flow rate can be set variably by way of a control element, which receives appropriate signals for setting the desired or most advantageous flow rate for the respective position of the spraying apparatus along the bore to be coated. In a preferred embodiment, the control element can be a rapidly openable solenoid valve, which preferably controls the flow steplessly. In an expedient refinement, the control element is arranged in the respective feed line for the respective gas.

[0023] It goes without saying that the process according to the invention can also be used for coating other components.

[0024] Further details of the invention become evident from the figures. In the figures:

[0025] FIG. 1 shows a schematic view of a plasma spraying apparatus for carrying out the process; and

[0026] FIG. 2 shows a schematic section through a cylinder bore with a coating produced by the process.

[0027] FIG. 1 shows a nozzle unit 1 of a PTWA internal coating apparatus. The PTWA (Plasma Transferred Wire Arc) coating system is a system for coating bores, in particular cylinders in engine blocks of internal combustion engines. The nozzle unit 1 consists of a cathode 2, a plasma nozzle 3 and the electrically conductive alloy wire 4 as anode, which is fed perpendicularly to the plasma nozzle 3. The material used for the cathode 2 is preferably tungsten, which may also be doped with thorium, for example. The plasma gas 5, for example a mixture of argon and hydrogen, is fed through bores made in the nozzle body 6 and lying tangentially to the circumference. The cathode holder 7 isolates the cathode 2 from the nozzle body 6. The alloy wire 4 is guided in the wire feed 15 such that it can move in rotation and be displaced longitudinally.

[0028] The process is started by a high-voltage discharge, which ionizes and dissociates the plasma gas 5 between alloy wire 4, nozzle body 6 and cathode 2. The thus produced plasma flows through the plasma nozzle 3 at high speed. In the process, the plasma gas 5 is transported toward the alloy wire 4 fed continuously perpendicularly to the nozzle 3, as a result of which the electric circuit is completed.

[0029] In addition, a transporting gas 9 or an atomizer gas 9 is fed via feed ducts 10 and auxiliary nozzles 11 to the plasma jet 8 emerging from the plasma nozzle 3.

[0030] The melting and the atomization of the alloy wire 4 are influenced in this case by two phenomena. The wire 4 is firstly resistance heated by large current intensities, which are typically 65-90 amperes. The impact of the plasma jet 8 on the preheated wire 4 ensures that the latter melts at the wire end 12. In other words, a plasma is generated inside the plasma nozzle 3 by means of high-voltage discharge. A targeted nitrogen gas flow, i.e., the transporting gas 9, along the discharge path transports the plasma and the molten spraying material 13 onto the surface 14 of the cylinder bore to be coated.

[0031] In the case of such a plasma spraying apparatus, the flow rate of the plasma gas 5 and/or of the transporting gas 9 is, according to the invention, variable along the longitudinal axis of the bore.

[0032] FIG. 2 shows a schematic section through a cylinder bore 16 with a coating 14, in which the coating 14 has been produced with a flow rate of the gas or gases which was varied over the axial length X. In principle, and merely by way of example, the coating is split into five regions, the dimensions of the regions shown, i.e. the axial extent thereof, merely being exemplary. The spraying procedure using the PTWA internal coating process began in a top cover region 17. The spraying apparatus was moved from the top cover region 17 toward the opposite end 18, the nozzle unit 1 rotating as described above. A top dead center region 19 adjoining the top cover region 17 can be seen. The top dead center region 19 is adjacent to a central region 20, which is adjacent to a bottom dead center region 21. This is adjacent to a bottom foot region 22.

[0033] Spraying was performed at a high flow rate in the top cover region 17 but also in the central region 20 and also in the bottom foot region 22, and therefore the coating has a low pore proportion in the respective region. By contrast, spraying was performed at a low flow rate in the top dead center region 19 and in the bottom dead center region 21, and therefore the coating has a high pore proportion in the respective
The region 21 is optional, and therefore the coating may also include only the regions 17, 19 and 20, where the central region 20 continues as far as the end 18, and where spraying was performed at a high flow rate, and therefore the coating can then have a low pore proportion in the respective region 17 and 20 (as far as the end 18).

1. A process for producing a coating by thermal spraying, including by plasma spraying, comprising:
- internally coating a component including a cylinder liner, with an alloy, wherein a plasma nozzle, to which a plasma gas is fed, and auxiliary nozzles, to which a transporting gas is fed, rotate about a wire and move along a longitudinal axis of a bore, such that the bore is coated as seen from the inside all around and in an axial direction of the bore, wherein
- a variable gas stream or a variable flow rate of the transporting gas and/or of a plasma gas set over an axial length (x) of the bore to be coated.

2. The process as claimed in claim 1, wherein the plasma spraying is a PTWA internal coating.

3. The process as claimed in claim 1, wherein the wire is a homogeneous wire.

4. The process as claimed in claim 1, wherein a low pore proportion can be set in the coating with a high flow rate of the plasma gas and/or of the transporting gas.

5. The process as claimed in claim 1, wherein a flow rate in a top dead center region has a lower value, and wherein
- a flow rate in a top cover region and in a central region has a higher value.

6. (canceled)

7. The process as claimed in claim 1, wherein provision is made of a control element, which controls a flow rate of the transporting gas and/or of the plasma gas depending on an axial position of a plasma spraying apparatus inside the bore, it being possible for the control element configured as a solenoid valve.

8. The process as claimed in claim 7, wherein the variable gas stream or the variable flow rate of the transporting gas and/or of the plasma gas set variably during the coating operation depending on the axial position inside the bore to be coated.