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(54) **A method for plasma-coating of rolls and a plasma-coated roll**

(57) A method for plasma-coating of rolls by forming a ceramic layer on the roll surface with a plasma plume emitted by a plasma spray apparatus, the plasma plume containing a powdered coating material, wherein the coating material is applied to the roll in a plurality of spiral passes of the plume along the roll. The plasma plume emitted by the plasma spray apparatus is limited by a

ceramic disc (14) mounted in the path of the plasma plume and having an aperture (15) via which only the hot zone of the plasma plume is transmitted, and wherein the spiral passes of the plume along the roll are delayed by an angle dependent on the number of spiral passes to be applied to the roll, such as to be distributed evenly along the roll.

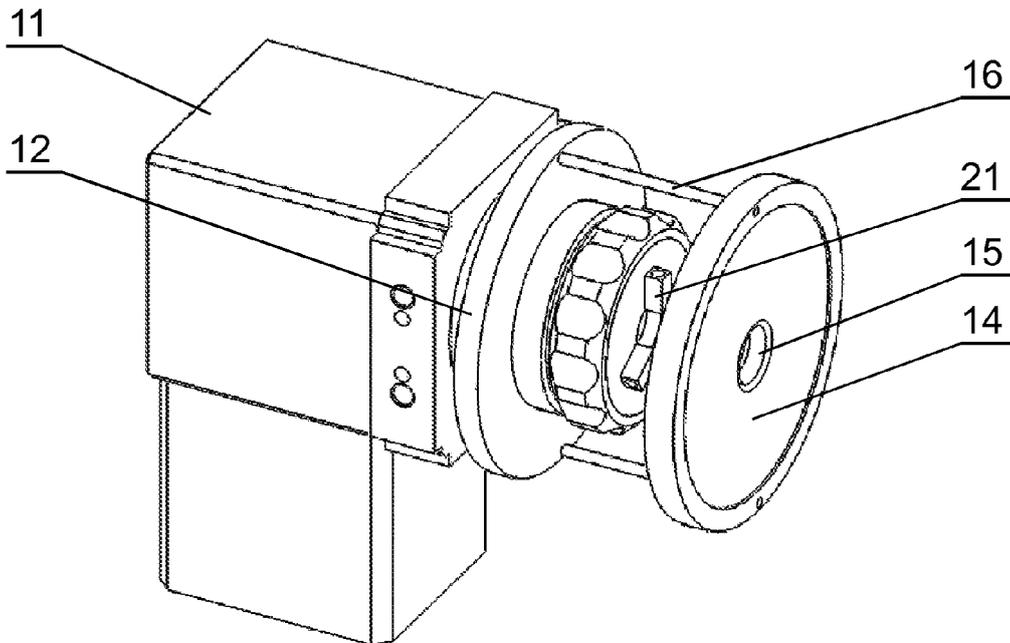


Fig. 2

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Description

[0001] The present invention relates to plasma-coating of rolls, such as anilox rolls.

[0002] An anilox roll is a cylinder used to deliver a certain amount of ink to a flexographic printing plate. The anilox roll has a metal core coated by ceramic material, such as Cr_2O_3 , the surface of which contains fine cells engraved by laser. The amount of ink that is transferred to the plate depends on the angle of the cells, cell volume and line screen (specifying the number of cells per linear inch). The development of flexographic printing technology requires anilox rolls of increasing line screen. This can be achieved by increasing the precision and resolution of laser engraving. However, increased line screen also requires increased quality, i.e. uniformness, of the ceramic coating that is engraved.

[0003] An exemplary process for making anilox rolls is presented in US patent application US 2010/0015354, wherein the anilox roll is manufactured by blurring a roller surface, forming a ceramic layer on the roller surface, grinding the roller surface, polishing the roller surface, forming a pattern on the roller surface using laser, polishing the roller surface and cleaning the roller surface.

[0004] In the plasma coating process, a high frequency arc ionizes a gas flowing between electrodes such that a plasma plume which is several centimeters in length develops. The temperature within the plume can reach $16,000^\circ\text{C}$. Into the plasma plume a material in powder form, such as Cr_2O_3 is injected. It is melted and propelled at high speed to the roll surface, where it rapidly cools and forms the coating of the roll. The roll is coated by performing a plurality of spiral passes of the spray along the roll. Usually, a few dozen passes are performed over the roll.

[0005] Conventional coating systems have certain limits that are not acceptable for high-quality anilox rolls coatings, such as high porosity (in the range of 4-6%, which limits the raster size to about 400 lines/cm) and unevenness of the coating (related to separation of layers).

[0006] Certain improvements have been introduced to conventional coating systems, such as the Triplex system by Sulzer Metco company, as described in US patents 5225652 and 5406046. It provides porosity reduced to 1,6-2% and high effectiveness, above 50%. Such system allows reduction of time and costs for processing the coating. Lower porosity allows engraving smaller cells and lower probability of unevenness of the coating.

[0007] The aim of the present invention is to provide further improvements to coating of anilox rolls.

[0008] The object of the invention is a method for plasma-coating of rolls by forming a ceramic layer on the roll surface with a plasma plume emitted by a plasma spray apparatus, the plasma plume containing a powdered coating material, wherein the coating material is applied to the roll in a plurality of spiral passes of the plume along the roll, wherein the plasma plume emitted by the plasma

spray apparatus is limited by a ceramic disc (14) mounted in the path of the plasma plume and having an aperture (15) via which only the hot zone of the plasma plume is transmitted, and wherein the spiral passes of the plume along the roll are delayed by an angle dependent on the number of spiral passes to be applied to the roll, such as to be distributed evenly along the roll.

[0009] Preferably, the delay angle between the passes is a prime number.

[0010] Preferably, the delay angle is not less than 23 degrees.

[0011] Preferably, the spiral passes of the plume are grouped in sets, wherein the passes of one set are delayed between each other by an angle different than the angle of delay for passes of another set.

[0012] Another object of the invention is a roll, in particular an anilox roll, plasma-coated by the method according to the invention.

[0013] The invention is shown by means of an exemplary embodiment on a drawing, in which:

Figs. 1A, 1B show the concept of temperature variation in the plasma plume.

Fig. 2 shows a plasma spray apparatus,

Figs. 3A-3F show various spray passes,

[0014] The present invention takes into account the results of the research work presented by Liangde Xie et al. in an article "Processing parameter effects on solution precursor plasma spray process spray patterns" (Surface and Coatings Technology 183 (2004), pp. 51-61). The article shows that the plasma plume has a large temperature variation, as shown in Fig. 1A. The precursor droplets fed into the plasma regions at different temperature will experience different physical and chemical reactions. During the fixed scan spray, the first coating material arriving at a given location in the substrate comes from the outer or colder region of the plasma jet, and is in the form of powdery deposits, as illustrated in Fig. 1B. The powdery deposits are then covered over by the coating material from the hotter region of the plasma jet for locations near the axis of the plasma torch and by the material from colder part of the plasma jet at all other locations. Therefore, the adherent deposits in the sample are a mixture of the coating material from both the hot and cold regions, and the powdery deposits originate only from the precursor fed into the cold region of the plasma jet. The hot zone is the zone in which the plasma plume has a temperature over 3400°C and the cold zone is the zone in which the plasma plume has a temperature below about 1200°C .

[0015] The present invention develops this concept by providing a plasma spray apparatus equipped with a ceramic aperture as shown in Fig. 2. The plasma spray apparatus comprises a rear gun body 11, to which a front gun body 12 is connected. The front gun body comprises an insulator block, neutrode insulator housing, electrodes and neutrode stack and nozzle (inside front gun

body, not shown for clarity). A powder injector 13 is installed at the front of the front gun body 12. In addition to the conventional elements 11-13, the plasma spray apparatus according to the invention comprises a ceramic disc 14 with a central aperture 15 mounted on holders 16 attached to the front gun body 12. The central aperture blocks the outer cold zone (region) of the plasma plume exiting the gun. The length of the holders 16 is adjustable so that the distance of the aperture 15 from the plasma gun can be adapted to a particular application. The ceramic disc 14 is formed of a ceramic material, such as Carbon/Graphite, that can withstand high temperatures, i.e. temperatures up to 3000°C and has a non-sticking surface, i.e. a surface to which the powdered material from the cold zone of the plasma plume will not adhere. The disc may have a diameter of about 100 mm and width of about 8 mm. The aperture 15 can have a diameter of about 12-15 mm. The aperture 15 may have conical edges with fillets at the entrance to make it aerodynamic and avoid introduction of turbulences in the plasma plume.

[0016] By introducing the ceramic disc into the plasma plume, the cold zone of the plume is blocked from reaching the roll being coated, and therefore a much higher ratio of adherent deposit with respect to powdery deposits is achieved on the roll, which increases the coating density and uniformity.

[0017] Due to a limited width of the plasma plume, the roll has to be coated a plurality of times, for example the plasma plume passes over the roll in a spiral manner a few dozen times. In case the width of the plume is reduced, the coating process has to be accurately controlled in order to avoid build-up of patterns along the roll, which make the coating non-uniform.

[0018] When the plasma gun coats the roll and reaches the end of the roll, a certain angular delay has to be introduced, so that the coating in the opposite direction is not followed along the same path as the previous pass, which would result in a pattern such as shown in Fig. 3A. The angular delay has to be chosen appropriately, such as to limit forming patterns. Fig. 3B shows a roll coated with 15 double passes of the plasma gun, wherein an angular delay of 7 degrees has been introduced at the front of the roll and no angular delay has been introduced at the end of the roll - such delay will result in unacceptable, uneven coating.

[0019] In turn, Fig. 3C shows a roll coated with 15 double passes of the plasma gun, wherein an angular delay of 23 degrees has been introduced at the front and at the end of the roll - the lines are distributed evenly, which guarantees even coating. For more detailed analysis of this case, Fig. 3A shows the roll after 1 pass, Fig. 3D shows the roll after 5 passes with the delay of 23 degrees, Fig. 3E shows the roll after 10 passes.

[0020] The delay has to be selected depending on the number of passes to be applied to the roll. For example, for the coating scheme as shown in Fig. 3D, the following angular delays have proved to be effective depending on the number of passes:

- For 1 double pass, the delay should be 179 degrees
- For 2 double passes delay should be 89 degrees (as shown in Fig. 3G)
- For 3 double passes delay should be 59 degrees
- For 4 double passes delay should be 43 degrees
- For 5 double passes delay should be 37 degrees (as shown in Fig. 3G)
- For 6 double passes delay should be 29 degrees
- For 7 double passes delay should be 23 degrees

[0021] The delay is the largest prime number which is smaller than the division of 180 degrees by the number of double passes. By selecting the delay to be a prime number, it is guaranteed that the passes will not overlay.

[0022] In practice, delays should not be less than 23 degrees, as the passes would be too close to each other. Therefore, in case more than 7 double passes are to be applied to the roll, they should be grouped in sets not larger than 7 double passes. Then, each set should be applied with a delay for the particular group. For example, if 16 double passes are required, they should be performed in three blocks: 3 double passes with a delay of 59 degrees, 6 double passes with a delay of 29 degrees and 7 double passes with a delay of 23 degrees. By selecting the delay to be a prime number, it is guaranteed that the passes will not overlap.

Claims

1. A method for plasma-coating of rolls by forming a ceramic layer on the roll surface with a plasma plume emitted by a plasma spray apparatus, the plasma plume containing a powdered coating material, wherein the coating material is applied to the roll in a plurality of spiral passes of the plume along the roll, **characterized in that** the plasma plume emitted by the plasma spray apparatus is limited by a ceramic disc (14) mounted in the path of the plasma plume and having an aperture (15) via which only the hot zone of the plasma plume is transmitted, and wherein the spiral passes of the plume along the roll are delayed by an angle dependent on the number of spiral passes to be applied to the roll, such as to be distributed evenly along the roll.
2. The method according to claim 1, wherein the delay angle between the passes is a prime number.
3. The method according to claim 1, wherein the delay angle is not less than 23 degrees.
4. The method according to claim 1, wherein the spiral passes of the plume are grouped in sets, wherein the passes of one set are delayed between each other by an angle different than the angle of delay for passes of another set.

5. A roll plasma-coated by the method of any of claims 1-4.
6. An anilox roll plasma-coated by the method of any of claims 1-4.

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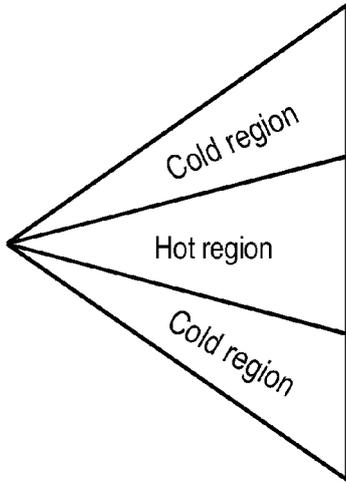


Fig. 1A

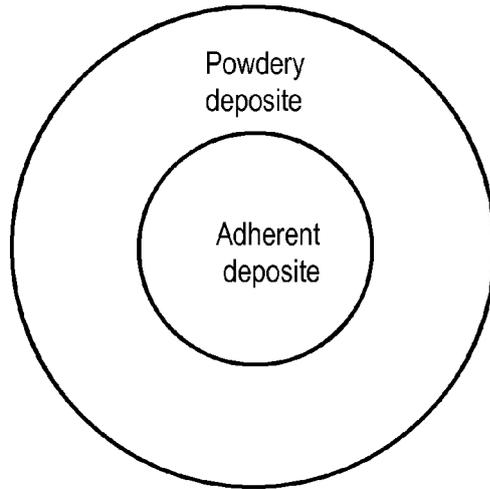


Fig. 1B

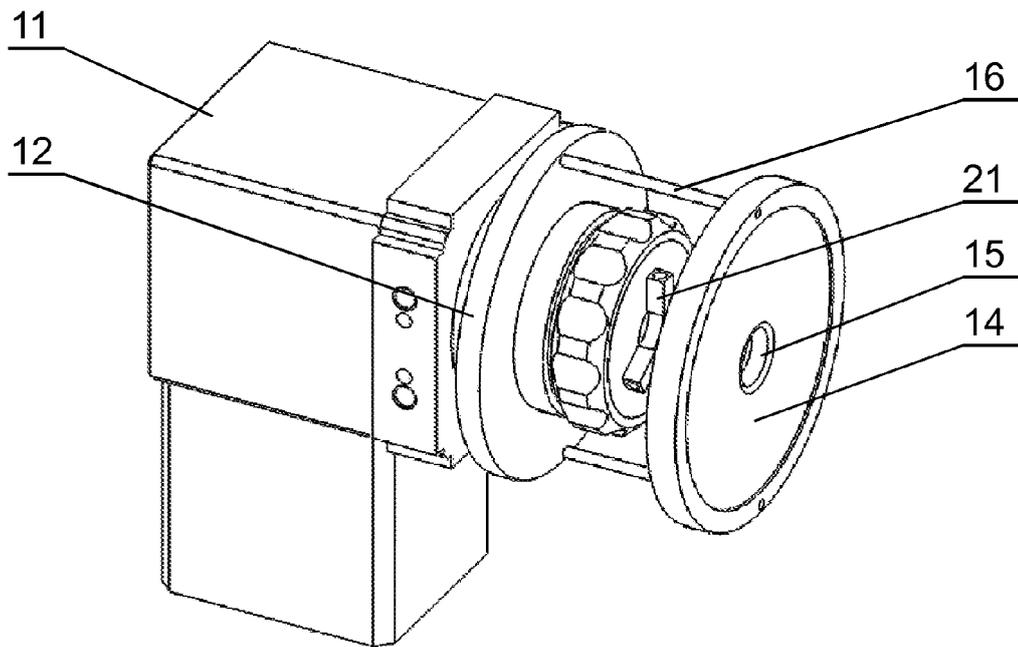


Fig. 2

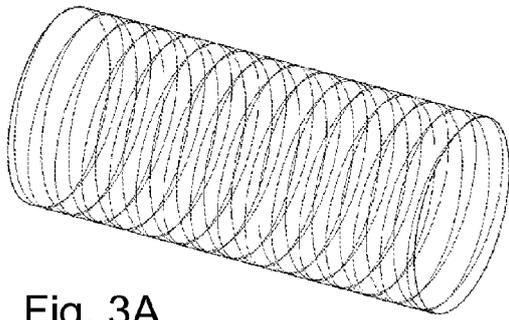


Fig. 3A

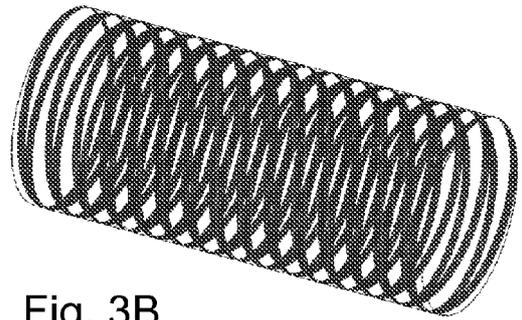


Fig. 3B

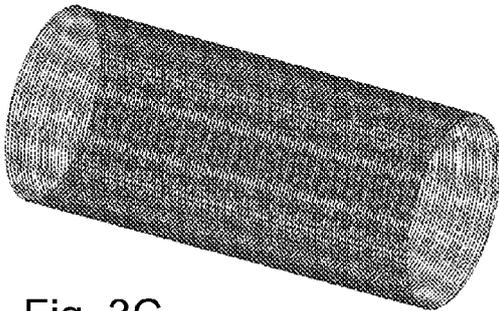


Fig. 3C

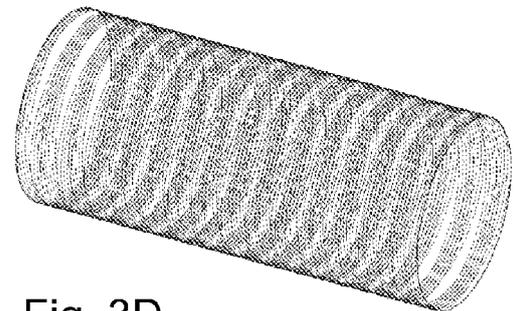


Fig. 3D

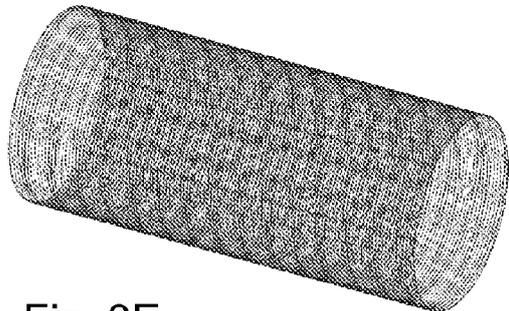


Fig. 3E

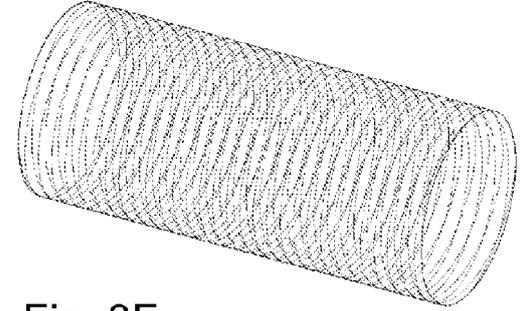


Fig. 3F

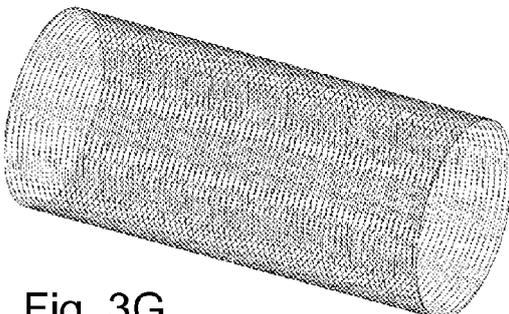


Fig. 3G



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Application Number
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The Hague		23 September 2011	Chalaftris, Georgios
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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