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(54) METHOD FOR TREATMENT OF GALVANISED OR GALVANNEALED STEEL

VERFAHREN ZUR BEHANDLUNG VON GALVANISIERTEM ODER GALVANNEALED-STAHL

MÉTHODE DE TRAITEMENT D'ACIER GALVANISÉ OU RECUIT PAR GALVANISATION

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Description

[0001] The invention relates to a method of treating a substrate, comprising:

- providing an applicator roll (2,3) contacting the substrate (5) which travels at a certain line speed;
- supplying a coating liquid (10) to the applicator roll (2,3) and thereby to the substrate (5),
- applying the coating liquid (10) as a substantially uniform layer of liquid coating (10) onto the substrate (5),

wherein a contact angle θ is defined as the angle, measured -in a static situation- through the coating liquid, where the liquid-vapour interface of the coating liquid meets the solid surface of the applicator roll;

[0002] Such a method is known from WO 2016/200866.

[0003] According to WO2016/200866 so-called ribbing defects are often observed in conventional roll coating processes for liquid coatings, for example, when the coating liquid has a viscosity of about 0.1 mPa.s or greater. The defects may occur as a coating liquid passes through a nip between rolls and the viscous stress at a film split overcomes surface tension forces attempting to maintain a uniform curvature of the interface at the film split.

[0004] WO2016/200866 teaches that the balance of viscous to surface tension forces can be described by a dimensionless capillary number defined by the equation $Ca = \mu U / \sigma$, wherein Ca is the capillary number, μ is a liquid viscosity, U is an average speed of first and second rolls, and σ is the liquid surface tension. The ribbing defect may according to this document lead to a highly non-uniform coating as the liquid exits the nip. To address this problem it may be necessary to limit line speeds. Other problems are that it may reduce the coating efficiency, and increase the cost of production. Additionally according to this document, as line speeds are increased it can lead to misting, for example, ejection of small droplets in the form of a mist, which can be a concern for the health and safety of the factory environment.

[0005] The problem of the ribbing defect is a long-lasting one; reference is made to the article "Ribbing Instability of a Two-roll Coater: Newtonian fluids" by J. Greener et al, published in Chem. Eng. Common, Vol. 5, pp. 73 - 83, published by Gordon and Breach, Science Publishers Inc. 1980, in which already an effort is made to understand the physical background of the ribbing defect. Its physical background is however unruly and hard to understand, which explains that the authors of said article exhale in discussing the theory known at the time: "Why does the theory of Savage fit the data so well in the case of the roll rotating near a fixed plate? We are unable to offer an explanation for this."

[0006] There are indeed many factors that play a role in the emergence of the ribbing defect. Mention can be made of roll properties such as hardness, Young modulus, viscoelastic, roll layer thickness, compressibility, roll radius etc. Also properties of the applied coating liquid are of importance, such as density, surface tension, viscosity, viscoelasticity. And finally operating conditions such as roll speed, speed ratio, slip, the height of the nip between the rolls and the applied load, temperature and the like all seem to be factors that influence the occurrence of the ribbing defect.

[0007] According to WO2016/200866 the ribbing defect is cured by arranging that the first roll comprises a thin metal shell and a resilient layer, the thin metal shell encases the resilient layer there beneath, and the thin metal shell is capable of deflecting in unison with the resilient layer such that the thin metal shell is elastically deformable at the nip when in contact with the second roll.

[0008] In the particular field of treating strips of galvanised or galvanized steel the problems that are observed in WO2016/200866 equally apply, yet the solutions as taught by WO2016/200866 are unfit to be practised in this heavy industrial environment.

[0009] A method to transfer a coating film onto a coating object is known from US10022743 B2

It is therefore an object of the invention to counter the ribbing defect when treating a strip of galvanised or galvanized steel with a coating liquid.

[0010] It is another object of the invention to be able to provide a galvanised or galvanized steel with a coating liquid without reducing the line speed.

[0011] According to the invention a method and a galvanised or galvanized steel substrate treated with a coating liquid is provided in accordance with one or more of the appended claims.

[0012] In a first aspect of the invention a method is proposed comprising the steps of:

- providing that the substrate (5) is a metal strip (5');
- providing that -in forward coating mode or in reverse coating mode- the absolute value of the tangential speed of a surface area of the applicator roll (2, 3) contacting the substrate (5) substantially matches that of the line speed of the substrate (5);
- providing that the contact angle θ is 97° or smaller.

[0013] Forward coating mode means that the tangential speed of the surface area of the applicator roll and the line speed of the substrate are in the same direction. Reverse coating mode means that the tangential speed of the surface area of the applicator roll and the line speed are in opposite directions. The words "substantially matches" as used in

this claim mean that preventing the ribbing defect can be promoted by arranging that the absolute value of the said tangential speed of the surface area of the rolls contacting the substrate differs less than 50 % from the absolute value of the line speed.

[0014] The inventors have found that controlling the contact angle θ to 97° or below plays a decisive role in the reduction and prevention of the ribbing defect when treating a metal strip.

[0015] In a further aspect of the invention the method comprises:

- providing that the contact angle θ is 93° or smaller and more preferably:
- is 80° or smaller.

[0016] The mentioned 97° is an upper limit; more favourable results are achievable by providing that the contact angle θ is smaller than 93°, more preferably even smaller than 80°. Where the ribbing result at contact angles θ from 93° to 97° varies from good to excellent, it is very good to excellent at 80° or smaller.

[0017] In a further aspect of the invention a method is proposed comprising:

- providing that at least one applicator roll (2, 3) has a polymer cover, wherein the tangential speed of the surface area of the applicator roll (2, 3) differs 30 % or less, preferably 20 % or less, and most preferably 10 % or less up or down with respect to the line speed of the substrate (5).

[0018] This leads to a better quality of the surface of the treated substrate and less applicator roll wear.

[0019] The treatment of the galvanised or galvanized steel is carried out by arranging that at least one of the applicator rolls has a polymer cover and where the method is used in forward coating mode, that the coating liquid (10) is applied to the substrate (5) as a thin wet film having a thickness of 4 μm or less, preferably 3 μm or less, and where the method is used in reverse coating mode, that the coating liquid (10) is applied to the substrate (5) as a thin wet film of less than 8 μm , preferably less than 6 μm , more preferably less than 4 μm . This results in a very efficient and effective application of coating liquid without occurrence of the ribbing defect.

[0020] The invention has been found to work well if the metal substrate is already coated, preferably zinc based coated, e.g. is a galvanised or galvanized steel substrate or a substrate with a zinc coating alloyed with aluminium and magnesium such as Magizinc®.

[0021] The result of the method of the invention is e.g. a galvanised or galvanized steel treated with the coating liquid, wherein ribbing defects are effectively avoided.

[0022] The invention will hereinafter be further elucidated with reference to the drawing of an exemplary embodiment of an apparatus employing the method according to the invention that is not limiting as to the appended claims.

[0023] In the drawing:

Figure 1 shows an apparatus employing the method according to the invention.

Figure 2 shows a diagram explaining the principles determining the contact angle θ .

Figure 3 shows contact angles measured using coating liquids designated as 10% and 20% in combination with materials of the surface of the applicator roll designated as rubbers A - N.

[0024] Figure 1 shows an apparatus 1 comprising a first applicator roll 2, a second applicator roll 3, and a nip 4 between the first and second applicator rolls 2, 3. Through the nip 4 between the first applicator roll 2 and the second applicator roll 3 a substrate 5 in the form of a galvanised or galvanized steel strip 5' moves with a predefined speed in the direction of arrow b. With the first applicator roll 2 and the second applicator roll 3 the steel strip 5' is coated on both sides with a coating liquid 10 (normally but not necessarily the same on each side) that is stored in and retrieved from tanks 6, 7. Supporting or pick-up rolls 8, 9 are rotating within the tanks 6, 7 to pick up the coating liquid 10 from these tanks 6, 7. As the supporting rolls 8, 9 are in contact with the earlier mentioned first applicator roll 2 and second applicator roll 3 a transfer of the coating liquid 10 from the pick-up rolls 8, 9 to these latter applicator rolls 2, 3 takes place. The applicator rolls 2, 3 can subsequently provide the coating liquid 10 to both sides of the metal strip 5'. It is of course also possible to arrange the apparatus 1 in a way that coating liquid 10 will be provided on only one side of the metal strip 5'. The ways in which this may be implemented are known to a person skilled in the art, so it is not necessary to provide a more detailed description thereof.

[0025] With the action of the applicator rolls 2, 3 on the metal strip 5' a further smoothing of the coating liquid 10 which is passed on to the metal strip 5' in the nip 4, is arranged which results into a substantially uniform layer of liquid coating 10 on the metal strip 5.

[0026] Figure 1 shows that the applicator roll 2 is counter-rotating with a tangential speed as symbolized with arrow c, and which is opposite (reverse coating mode) to the movement direction of the metal strip 5' symbolized by the arrow b. In reverse coating mode, the strip will carry almost all (more than 95%) of the coating to the strip. Such a reverse

operation is however only one possible option, another common option which is within the scope of the invention is that the roll 2 has a tangential speed which is in the same direction as the movement direction b of the metal strip 5 (forward coating mode). Arrow c is then pointing in a direction opposite to the one shown in figure 1. In forward coating mode the strip will only carry about 50% of the coating to the strip, the remainder of the coating staying on the applicator roll 2, 3.

[0027] The contact angle θ is symbolized in figure 2 with the letter ' θ '. The contact angle θ is defined as the angle where -in equilibrium- the liquid-ambient-atmosphere-interface meets the solid surface of the applicator roll (2, 3), see figure 2. In figure 2 the horizontal line represents the solid surface of the applicator roll (2,3) and the curved line represents the abovementioned interface.

[0028] Practical values for the tangential speed of the surface area of the rolls 2, 3 and the line speed of the substrate 5 are that each speed is set in the range of 50 to 140 m/min. The results of the invention are supported by the findings as shown in figure 3 and in the following tables.

[0029] A large amount of applicator rolls with surface layers of different rubbers was obtained from different suppliers as follows:

Table 1 Materials for surface of applicator roll

Name	Description	Hardnes s (Shore)
A	Modified EPDM rubber	50
B	Modified EPDM rubber	50
C	PUR abrasion resistant	60
D	PUR roller coating grade	55
E	EDPM roller coating grade	50
F	Modified PUR non roller coating	55
G	Modified PUR roller coating	55
H	Modified abrasion resistant PUR	70
I	Modified EDPM for chemicals	60
J	Modified EDPM	60
K	Modified EDPM for Rolling coating	60
L	Modified PUR acid resistant	70
M	Special PUR coating	55
N	Modified EDPM for chemicals	60

[0030] As it was expected that the concentration could have an influence this was varied as well. Two concentrations normally used in manufacturing, a so called 10 % concentration and a 20 % concentration were used. The results of the contact angle measurements is shown in figure 3.

[0031] Then for applicator rolls with rubbers A, B, E, K and M the ribbing results were established in a commercial line, using the two concentrations mentioned above, with the results as shown in table 2:

Table 2 Ribbing result at 10% resp. 20% concentration

Name	Ribbing result 10 %	Ribbing Result 20 %
A	Excellent	Very Good
B	Excellent	Good
E	Bad	Bad
K	Average	Average
M	Average	Very Good

[0032] In accordance with these results and referring also to figure 3 it is preferred that the contact angle θ is 97° or smaller, and more preferably that the contact angle θ is 93° and even more preferably that is is 80° or smaller.

[0033] Although the experiment shows the application of a coating liquid 10 in a single step, it is preferred with a view to achieve best results that different coating liquids may be provided onto the metal strip 5 in subsequent steps, using customary post treatment liquids in customary concentrations of e.g. 10 - 30 %, the remainder being water.

[0034] Finally it is remarked that the invention is also embodied in a galvanised or galvanized steel strip 5 treated with a coating liquid 10 as provided on the metal strip 5 in accordance with the method of the invention.

[0035] Although the invention has been discussed in the foregoing with reference to an exemplary embodiment of the method of the invention, the invention is not restricted to this particular embodiment which can be varied in many ways without departing from the invention. The discussed exemplary embodiment shall therefore not be used to construe the appended claims strictly in accordance therewith. On the contrary the embodiment is merely intended to explain the wording of the appended claims without intent to limit the claims to this exemplary embodiment. The scope of protection of the invention shall therefore be construed in accordance with the appended claims only, wherein a possible ambiguity in the wording of the claims shall be resolved using this exemplary embodiment.

Claims

1. A method of treating a substrate, comprising:

- providing an applicator roll (2,3) contacting the substrate (5) which travels at a certain line speed;
- supplying a coating liquid (10) to the applicator roll (2,3) and thereby to the substrate (5),
- applying the coating liquid (10) as a substantially uniform layer of liquid coating (10) onto the substrate (5), wherein a contact angle θ is defined as the angle, measured -in equilibrium- through the coating liquid, where the liquid-vapour interface of the coating liquid meets the solid surface of the applicator roll;

characterized by

- providing that the substrate (5) is a metal strip (5');
 - providing that -in forward coating mode or in reverse coating mode- the absolute value of the tangential speed of a surface area of the applicator roll (2, 3) contacting the substrate (5) substantially matches that of the line speed of the substrate (5);
 - providing that the contact angle θ is 97° or smaller,
- wherein the method is used in forward coating mode, providing that at least one applicator roll (2, 3) has a polymer cover and that the coating liquid (10) is applied to the substrate (5) as a thin wet film having a thickness of $4\text{ }\mu\text{m}$ or less; or
- wherein the method is used in reverse coating mode, providing that at least one applicator roll (2, 3) has a polymer cover and that the coating liquid (10) is applied to the substrate (5) as a thin wet film of less than $8\text{ }\mu\text{m}$.

2. Method according to claim 1, **characterized by** providing that the contact angle θ is 93° or smaller.

3. Method according to claim 1 or 2, **characterized by** providing that the contact angle θ is 80° or smaller.

4. Method according to any one of the previous claims, **characterized by** providing that at least one applicator roll (2, 3) has a polymer cover, wherein the tangential speed of the surface area of the applicator roll (2, 3) differs 30 % or less, preferably 20 % or less, and most preferably 10 % or less up or down with respect to the line speed of the substrate (5).

5. Method according to any one of the previous claims, wherein the method is used in forward coating mode, **characterized by** providing that at least one applicator roll (2, 3) has a polymer cover and that the coating liquid (10) is applied to the substrate (5) as a thin wet film having a thickness of $3\text{ }\mu\text{m}$ or less.

6. Method according to any one of the claims 1 to 4, wherein the method is used in reverse coating mode, **characterized by** providing that at least one applicator roll (2, 3) has a polymer cover and that the coating liquid (10) is applied to the substrate (5) as a thin wet film of less than $6\text{ }\mu\text{m}$, more preferably less than $4\text{ }\mu\text{m}$.

7. Method according to any one of the previous claims, wherein the metal substrate is coated, preferably zinc based coated, e.g. is a galvanised or galvanized steel substrate.

Patentansprüche

1. Verfahren zum Behandeln eines Substrats, umfassend:

- Bereitstellen einer das Substrat (5) kontaktierenden Auftragswalze (2, 3), die sich mit einer gewissen Liniengeschwindigkeit bewegt;
- Zuführen einer Beschichtungsflüssigkeit (10) zu der Auftragswalze (2,3) und dadurch zu dem Substrat (5),
- Auftragen der Beschichtungsflüssigkeit (10) als im Wesentlichen gleichmäßige Schicht Flüssigbeschichtung (10) auf das Substrat (5),

wobei ein Kontaktwinkel θ als der - im Gleichgewicht - durch die Beschichtungsflüssigkeit gemessene Winkel definiert ist, wo die Flüssigkeit-Dampf-Grenzfläche der Beschichtungsflüssigkeit auf die feste Oberfläche der Auftragswalze trifft;

gekennzeichnet durch

- Bereitstellen, dass das Substrat (5) ein Metallstreifen (5') ist;
- Bereitstellen, dass - in einem Vorwärtsbeschichtungsmodus oder in einem Rückwärtsbeschichtungsmodus - der Absolutwert der Tangentialgeschwindigkeit eines Oberflächenbereichs der das Substrat (5) kontaktierenden Auftragswalze (2, 3) im Wesentlichen mit dem der Liniengeschwindigkeit des Substrats (5) übereinstimmt;
- Bereitstellen, dass der Kontaktwinkel θ 97° oder kleiner ist,

wobei das Verfahren im Vorwärtsbeschichtungsmodus verwendet wird, Bereitstellen, dass mindestens eine Auftragswalze (2, 3) einen Polymerüberzug aufweist und dass die Beschichtungsflüssigkeit (10) als dünner Nassfilm mit einer Dicke von $4\text{ }\mu\text{m}$ oder weniger auf das Substrat (5) aufgetragen wird; oder

wobei das Verfahren im Rückwärtsbeschichtungsmodus verwendet wird, Bereitstellen, dass mindestens eine Auftragswalze (2, 3) einen Polymerüberzug aufweist und dass die Beschichtungsflüssigkeit (10) als dünner Nassfilm von weniger als $8\text{ }\mu\text{m}$ auf das Substrat (5) aufgetragen wird.

2. Verfahren nach Anspruch 1, **gekennzeichnet durch** Bereitstellen, dass der Kontaktwinkel θ 93° oder kleiner ist.

3. Verfahren nach Anspruch 1 oder 2, **gekennzeichnet durch** Bereitstellen, dass der Kontaktwinkel θ 80° oder kleiner ist.

4. Verfahren nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** Bereitstellen, dass mindestens eine Auftragswalze (2, 3) einen Polymerüberzug aufweist, wobei die Tangentialgeschwindigkeit des Oberflächenbereichs der Auftragswalze (2, 3) in Bezug auf die Liniengeschwindigkeit des Substrats (5) um 30 % oder weniger, bevorzugt um 20 % oder weniger und am stärksten bevorzugt um 10 % oder weniger nach oben oder unten abweicht.

5. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Verfahren im Vorwärtsbeschichtungsmodus verwendet wird, **gekennzeichnet durch** Bereitstellen, dass mindestens eine Auftragswalze (2, 3) einen Polymerüberzug aufweist und dass die Beschichtungsflüssigkeit (10) als dünner Nassfilm mit einer Dicke von $3\text{ }\mu\text{m}$ oder weniger auf das Substrat (5) aufgetragen wird.

6. Verfahren nach einem der Ansprüche 1 bis 4, wobei das Verfahren im Rückwärtsbeschichtungsmodus verwendet wird, **gekennzeichnet durch** Bereitstellen, dass mindestens eine Auftragswalze (2, 3) einen Polymerüberzug aufweist und dass die Beschichtungsflüssigkeit (10) als dünner Nassfilm von weniger als $6\text{ }\mu\text{m}$, stärker bevorzugt weniger als $4\text{ }\mu\text{m}$ auf das Substrat (5) aufgetragen wird.

7. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Metallsubstrat beschichtet ist, bevorzugt auf Zinkbasis beschichtet ist, z. B. ein Substrat aus galvanisiertem oder Galvannealed-Stahl ist.

Revendications

1. Procédé de traitement d'un substrat, comprenant :

- la fourniture d'un rouleau applicateur (2, 3) en contact avec le substrat (5) qui se déplace à une certaine vitesse de ligne ;

- la fourniture d'un liquide de revêtement (10) au rouleau applicateur (2, 3) et ainsi au substrat (5),
- l'application du liquide de revêtement (10) sous la forme d'une couche sensiblement uniforme de revêtement liquide (10) sur le substrat (5),

5 un angle de contact θ étant défini comme l'angle, mesuré - à l'équilibre - à travers le liquide de revêtement, où l'interface liquide-vapeur du liquide de revêtement rencontre la surface solide du rouleau applicateur ; **caractérisé par**

- à condition que le substrat (5) soit une bande métallique (5') ;
- 10 - à condition que -en mode de revêtement avant ou en mode de revêtement inverse- la valeur absolue de la vitesse tangentielle d'une zone de surface du rouleau applicateur (2, 3) en contact avec le substrat (5) correspond sensiblement à celle de la vitesse linéaire du substrat (5) ;
- à condition que l'angle de contact θ soit inférieur ou égal à 97° ,

15 ledit procédé étant utilisé en mode de revêtement avant, à condition qu'au moins un rouleau applicateur (2, 3) comporte un recouvrement de polymère et que le liquide de revêtement (10) soit appliqué sur le substrat (5) sous la forme d'un mince film humide comportant une épaisseur inférieure ou égale à $4\text{ }\mu\text{m}$; ou ledit procédé étant utilisé en mode de revêtement inverse, à condition qu'au moins un rouleau applicateur (2, 3) comporte un recouvrement de polymère et que le liquide de revêtement (10) soit appliqué sur le substrat (5) sous la forme d'un mince film humide inférieur à $8\text{ }\mu\text{m}$.

2. Procédé selon la revendication 1, **caractérisé par** la condition que l'angle de contact θ soit inférieur ou égal à 93° .

25 3. Procédé selon la revendication 1 ou 2, **caractérisé par** la condition que l'angle de contact θ soit inférieur ou égal à 80° .

4. Procédé selon l'une des revendications précédentes, **caractérisé par** la condition qu'au moins un rouleau applicateur (2, 3) comporte un recouvrement de polymère, ladite vitesse tangentielle de la zone de surface du rouleau applicateur (2, 3) différant de 30 % ou moins, de préférence de 20 % ou moins, et mieux encore de 10 % ou moins, en hausse ou en baisse par rapport à la vitesse de ligne du substrat (5).

30 5. Procédé selon l'une quelconque des revendications précédentes, ledit procédé étant utilisé en mode de revêtement avant, **caractérisé par** la condition qu'au moins un rouleau applicateur (2, 3) comporte un recouvrement de polymère et que le liquide de revêtement (10) soit appliqué sur le substrat (5) sous la forme d'un mince film humide comportant une épaisseur inférieure ou égale à $3\text{ }\mu\text{m}$.

35 6. Procédé selon l'une quelconque des revendications 1 à 4, ledit procédé étant utilisé en mode de revêtement inverse, **caractérisé par** la condition qu'au moins un rouleau applicateur (2, 3) comporte un recouvrement de polymère et que le liquide de revêtement (10) soit appliqué au substrat (5) sous la forme d'un mince film humide inférieur à $6\text{ }\mu\text{m}$, de préférence inférieur à $4\text{ }\mu\text{m}$.

40 7. Procédé selon l'une quelconque des revendications précédentes, ledit substrat métallique étant revêtu, de préférence revêtu à base de zinc, par exemple ledit substrat métallique étant un substrat en acier galvanisé ou recuit par galvanisation.

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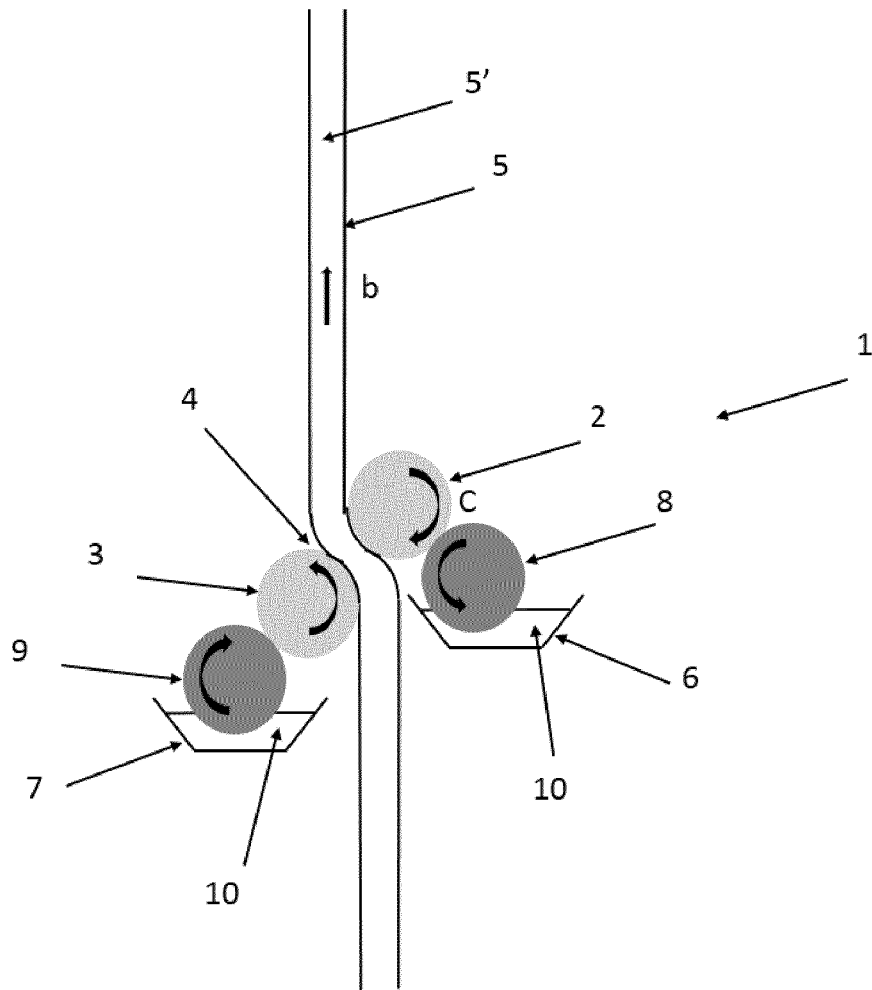


Fig. 1



Fig. 2

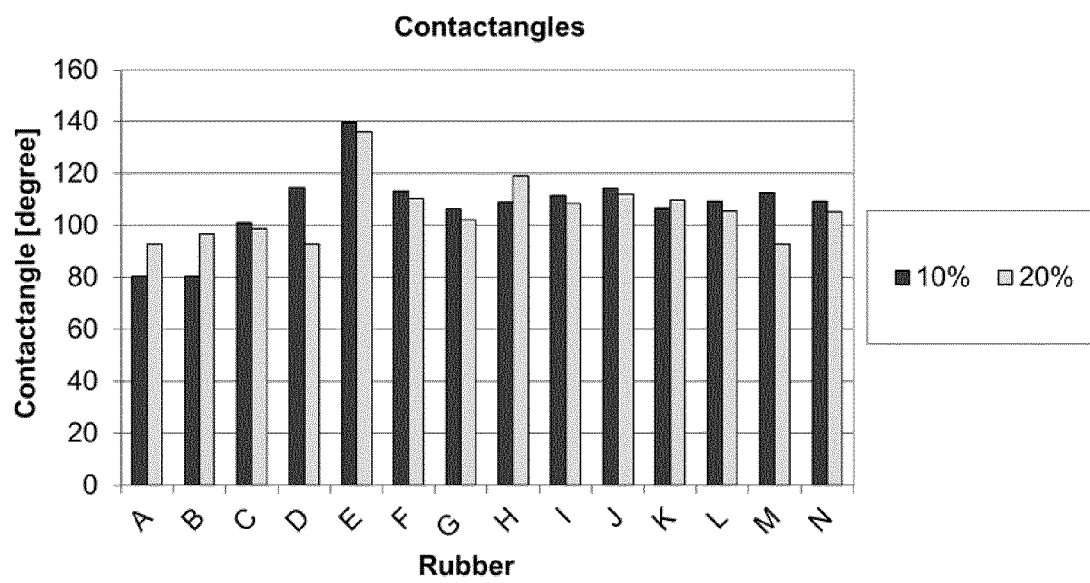


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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