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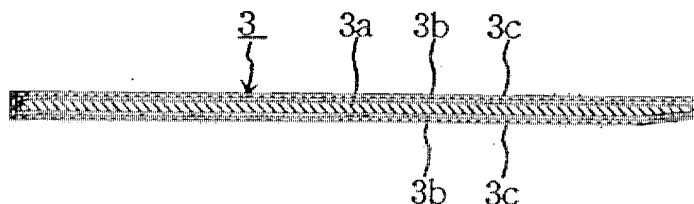
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(54) **Doctor blade**

(57) A doctor blade (3) that fills the cells of a gravure printing roller with ink and scrapes off any excess ink comprising a core (3a) composed of carbon steel or stainless steel and a diamond-like carbon coating (3c) coated on the core. An undercoat (3b) that is harder than the core (3a) and softer than the diamond-like carbon coating (3c) may be formed between the core and the diamond-like carbon coating. The diamond-like carbon coating (3c) is smooth and hard, has an extremely low

Young's modulus, is a flexible film, slides easily over the plate surface, stays close to the water-based ink lying in the sandpaper marks formed in the non-printing area of a plate surface, and keeps the amount of ink that goes under the doctor blade to a minimum. The doctor blade has excellent wear resistance, favorable ink removal can be continued indefinitely, and plate fogging can be effectively avoided. No plate fogging occurs even when the printing is carried out at a practical printing speed and for an extended printing length.

**F I G 2**



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## Description

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

**[0001]** The present invention relates to a doctor blade that is abutted against a gravure printing roller so as to fill the cells of the printing roller with ink and scrape off any excess ink.

#### 2. Prior Art

**[0002]** Figure 3 illustrates a doctor apparatus in a conventional gravure printer.

**[0003]** In Figure 3, the reference numeral 1 is a gravure printing roller and 2 is a doctor blade of the doctor apparatus. A doctor apparatus (not shown) supports the doctor blade 2, and the distal end of the doctor blade 2 is abutted against the gravure printing roller 1 so that the blade 2 can scrape off any excess ink from the surface of the roller 1. The distal end of the doctor blade 2 is shaped into a knife edge. The doctor blade 2 slowly slides laterally in the direction indicated by the arrow A during printing, so that a single point of the knife edge of the doctor blade 2 is prevented from always being in contact with just one point in the longitudinal direction on the surface of the gravure printing roller 1, thus ensuring that the distal edge can wear evenly.

**[0004]** If the doctor blade 2 does not slide laterally in the direction of arrow A during printing, the wear at the distal end of the doctor blade 2 would not be even, a few places along the distal end would wear faster than other places, and the ink scraping function at these places would be lost, resulting in continuous lines in the circumferential direction of the plate that are not present in the a plate image. In other words, the printing would have doctor streaks that occur in numerous unpredictable places.

**[0005]** Prior art pertaining to doctor blades includes Japanese Patent Application Laid-Open Nos. S61-12396, S62-227645, S62-238743, S62-503085, S63-25038, S63-116852, S63-246249, H3-007394, H4-012853, H4-070341, H4-070342, H4-296556, H6039991, 1.17-276601, H8-164598, H9-254356, H10-278222, and H10-337840, and Japanese Utility Model Application Laid-Open Nos. 562-005959 and S63-094576.

**[0006]** Nearly all of these publications relate to techniques that cat enhance the durability of doctor blades. The object of Japanese Patent Application Laid-Open No. H10-337840 is the elimination of plate fogging, but this invention has no effect in gravure printing with water-based ink.

**[0007]** U.S. Patents 5,638,151 and 4,895,071 also relate to doctor blades, but both are for improvements in the shape and support structure of the doctor blade.

**[0008]** Technological improvements have been made

in terms of plate fogging in gravure printing with oil-based ink. With gravure printing using water-based ink, however, there have been no technological improvements for plate fogging, and this printing therefore remains impractical. Up to now, the photogravure printing that is used to print soft packaging films, calendars, materials inserted into magazines and so on has always been accomplished by oil-based ink gravure printing.

**[0009]** As is clear from the prior arts cited above, all of the improvements and innovations related to doctor blades have up to now been proposed from the standpoints of enhancing wear resistance, increasing durability, eliminating doctor streaks, and eliminating the occurrence of whiskers. For example, if the ink contains titanium white or the like, the wear rate will be relatively high, so the question becomes how to impart wear resistance and extend the service life in order to lower the running cost of the doctor blade, which is a consumable pan.

**[0010]** In the past, there were no instances of a doctor blade being improved from the standpoint of eliminating plate fogging in water-based ink gravure printing to make such printing practical.

**[0011]** In oil-based ink gravure printing, the organic solvent that is contained in the oil-based ink in amounts over 50% volatilizes and contributes to atmospheric pollution, so there is a great deal of interest in converting to water-based ink gravure printing in which the alcohol content is only 5 to 10%.

**[0012]** Nevertheless, water-based ink gravure printing is extremely prone to plate fogging, and high-precision printing has been out of the question.

**[0013]** With gravure printing, a doctor blade is abutted against a gravure printing roller to fill the cells with ink and scrape off any excess ink, so in theory no ink remains behind on the non-printing area, but in actual practice plate fogging occurs because the ink goes under the doctor blade and remains in the non-printing area.

**[0014]** Plate fogging is a phenomenon in which ink goes under the doctor blade and remains in the non-printing area on the plate surface, and since this ink does not dry enough by the time it is printed, the ink is transferred to the printed matter and the image is soiled.

This phenomenon occurs when the printing rate is too high or the number of printed sheets is large, resulting in accelerated wear of the doctor blade.

**[0015]** Plate fogging is particularly pronounced when a water-based ink is used, and it is a very difficult problem to eradicate at the present time, but it also occurs when oil-based inks are used.

**[0016]** The mechanism by which plate fogging occurs will be described below.

**[0017]** In the following description, it is assumed that a roller surface is buffed to a extremely high-precision mirror surface, cells are then formed and chrome plating is performed to provide printing durability, the plating burrs are removed, and oil-based ink gravure printing is

performed with this extremely high-precision mirror surface. It is Also assumed that the doctor blade is equipped with a knife edge capable of performing an ink scraping function extremely well.

**[0018]** In the above situations, for a very brief time at the outset, the doctor blade is able to scrape the oil-based ink away from the non-printing area of the plate surface so that one whatsoever remains behind. However, the scraping of the ink in this process means that there is no lubricant present between the doctor blade and the plate surface. Consequently, the relative coefficient of friction between the doctor blade and the non-printing area of the plate surface becomes high, the doctor blade and the plate surface are prone to wear, the ink scraping function of the doctor blade decreases, and the plate surface soon becomes rough. When this happens, the oil-based ink goes past the doctor blade and remains in the non-printing area. This results in plate fogging. Also, if there is no lubricant present between the doctor blade and the plate surface, the frictional force that occurs correlatively between the doctor blade and the non-printing area of the plate surface, combined with the eccentricity of the printing roller, varies continuously and generates vibration. As a result, the oil-based ink passes the doctor blade and remains in the nonprinting area, thus producing a great deal of plate fogging.

**[0019]** In view of the above, a roller with surface roughness is buffed to an extremely high-precision mirror surface with a 2000 to 3000 grit whetstone, cells are formed thereon, chrome plating is performed so as to provide printing durability, any burrs are removed, and hand polishing is performed so that sandpaper marks remain with sufficient uniformity. By way of taking these steps, the plate surface may have self-lubricity; and as a result, printing in which no plate fogging will occur can be accomplished in oil-based ink gravure printing.

**[0020]** Self-lubricity of a plate surface can be described as follows:

**[0021]** Sandpaper marks are left in the non-printing area when the chrome plating that provides the plate surface with printing durability is rubbed with sandpaper. A doctor blade is abutted against the gravure printing roller to fill the cells with ink and scrape off any excess ink. Then, the minute amount of oil-based ink that fills the sandpaper marks goes under the doctor blade. The oil-based ink that remains in the sandpaper marks under the doctor blade contains very little pigment and a large proportion of resin and solvent. Also, when the oil-based ink that remains in the sandpaper marks goes under the doctor blade, the resin and solvent contained therein act as a lubricant between the doctor blade and the plate surface. Accordingly, the relative coefficient of friction between the doctor blade and the non-printing area of the plate surface becomes lower, and the wear of the doctor blade knife edge and wear of the plate surface can be kept low.

**[0022]** Since the minute amount of oil-based ink remaining in the sandpaper marks form an extremely thin

film, there is a remarkable increase in the proportional surface area exposed to the dried air, and the solvent in this oil-based ink volatilizes within a very short period of time until it reaches the printing location at a printing rate of 110 to 130 m/min. As a result, the pigment and resin are drawn to the bottom of the sandpaper marks, enter a lightly dried state, and are not transferred to the printed matter. The pigment and resin that are thus drawn to the bottom of the sandpaper marks and lightly dried are impregnated with solvent and wetted when again brought together with the oil-based ink applied thereover; thus they do not dry and build up at the bottom of the sandpaper marks. In other words, plate fogging does not occur over time with printing. If the printing rate is set to be high, however, the minute amount of oil-based ink that remains in the sandpaper marks formed in the non-printing area that goes under the doctor blade will not volatilize within the time that elapses until the printing location is reached. As a result, plate fogging occurs.

**[0023]** Described above is the reason that plate fogging does not occur if self-lubricity is imparted to the plate surface in oil-based ink gravure printing.

**[0024]** To the contrary, in gravure printing that uses a water-based ink the causal relationship between imparting self-lubricity to a plate surface and plate fogging not occurring cannot be said to be the same as in the oil-based ink gravure printing. The situation in which plate fogging occurs is different with water-based ink gravure printing.

**[0025]** First let us discuss the case when the roller surface is buffed to an extremely high-precision mirror surface, cells are formed thereon, chrome plating is performed to provide printing durability, the plating burrs are removed, and water-based ink gravure printing is performed with this extremely high-precision mirror surface.

**[0026]** Just as when the oil-based ink gravure printing discussed above is performed, for a very brief time at the outset, the doctor blade can scrape the water-based ink away from the non-printing area of the plate surface so that none whatsoever remains behind. However, because of the high relative coefficient of friction between the doctor blade and the non-printing area of the plate surface, there is rapid wear, and the surface soon becomes rough. As a result, the water-based ink passes by the doctor blade and remains in the non-printing area, causing much plate fogging.

**[0027]** In view of this, just as with oil-based ink gravure printing, a roller with surface roughness is buffed to an extremely high-precision mirror surface with a 2000 to 3000 grit whetstone, cells are then formed thereon, chrome plating is performed to provide printing durability, any burrs are removed, and hand polishing is performed so that sandpaper marks can remain with sufficient uniformity. As a result, the plate surface has self-lubricity. However, there will be pronounced plate fogging with water-based ink gravure printing, and high-precision printing is completely out of the question.

**[0028]** There are a number of compound causes of this.

**[0029]** Possible causes are as follows: because the concentration of pigment components is about 30% higher in a water-based ink than in an oil-based ink, the water-based ink that lies in the sandpaper marks and goes under the scraping of the doctor blade has a higher pigment concentration; because the drying of pigment through the evaporation of water involves a far higher drying load than the drying of pigment through the volatilization of an organic solvent, drying is slower, which means that the water-based ink that goes under the doctor blade will not dry sufficiently in the very short time before the printing position is reached, and particular, combined water that binds to pigments and resin does not readily volatilize; and because the pigment and resin that have been drawn to the bottom of the sandpaper marks and lightly dried have a lower affinity with water than with a solvent, even when they are again brought together with the water-based ink that is applied by a furnisher roller, it takes time for them to mix with the water or alcohol that are components of the ink, and they continue to accumulate at the bottom of the sandpaper marks. Furthermore, since a doctor blade composed of carbon steel has been used in the past, there is considerable wear after 20,000 meters of printing, and the knife edge is greatly worn down, so that the thickness of the knife edge of the doctor blade goes from an initial 55 gm to about 100 gin, which remarkably diminishes the ink scraping function thereof and increases the amount of water-based ink that goes under the doctor blade.

**[0030]** As seen from the above, though forming sandpaper marks in . no printing area does impart self-lubricity to the plate surface with water-based ink gravure printing, it does not solve the problem of plate fogging, and on the contrary actually causes plate fogging.

**[0031]** Accordingly, in water-based ink gravure printing, the relative lubricity between the doctor blade and the plate surface must be increased and plate fogging also must be prevented by some other means without forming sandpaper marks in the nonprinting area.

#### SUMMARY OF THE INVENTION

**[0032]** The present invention was conceived in light of the above-described prior art problems, and an object of the present invention is to provide a doctor blade that is abutted against a gravure printing roller so as to fill the cells with ink and scrape off any excess ink in which the service life of the doctor blade can be extended.

**[0033]** It is another object of the present invention to provide a doctor blade which is resistant to plate fogging even when used in gravure printing with a water-based ink at the same printing rate as in gravure printing with an oil-based ink.

**[0034]** It is still another object of the present invention to provide a doctor blade which allows gravure printing with water-based ink to, be brought to a practical level.

**[0035]** More specifically, the present invention provides a doctor blade whose distal end is abutted against a gravure printing roller to fill the cells with ink and scrape off any excess ink, wherein the doctor blade comprises: a metal core formed from a thin stainless steel sheet or a thin carbon steel sheet that is quench hardened and whose distal end has a knife edge, and a diamond-like carbon coating that at least coats both sides of the distal end of the core.

**[0036]** The present invention further provides a doctor blade whose distal end is abutted against a gravure printing roller to fill the cells with ink and scrape off any excess ink, wherein the doctor blade comprises a metal core formed from a thin stainless steel sheet or a thin carbon steel sheet that is quench hardened and whose distal end has a knife edge, a diamond-like carbon coating that over-coats at least both sides of the distal end of the core, and an undercoat that is provided between the core and the diamond-like carbon coating so as to coat at least one or both sides of the distal end of the core, the undercoat being harder than the core but softer than a diamond-like carbon coating and increasing the hardness of the core.

#### BRIEF DESCRIPTION OF THE DRAWINGS

##### **[0037]**

Figure 1 is a cross sectional view of the doctor blade according to the first embodiment of the present invention;

Figure 2 shows a cross sectional view of the doctor blade according to the second embodiment of the present invention; and

Figure 3 is a simplified oblique view of a conventional doctor apparatus.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

**[0038]** Embodiments of the doctor blade of the present invention will be described in detail below with reference to Figures 1 and 2.

**[0039]** The doctor blade 3 shown in Figure 1 comprises a core 3a and a diamond-like carbon coating 3c that coats the core 3a.

**[0040]** The doctor blade 3 shown in Figure 2 comprises a core 3a, an undercoat 3b that coats the core 3a, and a diamond-like carbon coating 3c that over-coats the undercoat 3b.

**[0041]** The doctor blade 3 of the first and second embodiments of the present invention will be described collectively.

**[0042]** The doctor blade 3 comes in different dimensions depending upon the size and mechanism of the gravure printing roller, but in specific terms the dimensions of the doctor blade 3 are 2200 to 1050 mm long x 60 to 80 mm wide x 120 to 180  $\mu$ m thick. One or both

sides has a knife edge with a thickness of about 50 to 70  $\mu\text{m}$  at the distal end. In the shown embodiments, the knife edge is formed on one side or on the right side in Figures 1 and 2. The location of this knife edge is determined according to the diameter of the gravure printing roller, and the knife edge is abutted against the gravure printing roller at an angle thereto, serving to scrape off any excess ink and to fill the cells of the gravure printing roller with ink.

**[0043]** The core 3a in the shown embodiments is formed from a thin steel sheet or stainless steel that is flexible without being too pliant, the distal end of which having a knife edge. If the core 3a is made of a steel sheet, it will be composed of carbon steel which has a Vickers hardness of approximately 600 when quenched. The term "knife edge" used here encompasses a wedge-shaped cross section where the thickness steadily decreases toward the distal end, as well as a stepped cross section where the distal end grows thinner in one or a plurality of steps.

**[0044]** The undercoat 3b is applied to one or both sides of the core 3a, on the ink scraping side, in a thickness of about 5 to 10  $\mu\text{m}$ . The undercoat 3b is provided in order to increase the wear strength of the core 3a and is composed of a plating material or a ceramic material that is harder than the core 3a. On the other hand, the undercoat 3b must be softer than the diamond-like carbon coating 3c. If the undercoat 3b is harder than the diamond-like carbon coating 3c, the wear strength of the core 3a will increase excessively, the diamond-like carbon coating 3c will wear down first, and the undercoat 3b will be exposed and end up scraping the ink off the plate surface. In addition, because the undercoat 3b has a high coefficient of sliding friction, it will rapidly wear down the plate surface. Also, because the undercoat 3b is hard and has a high Young's modulus, no special effect will be realized in terms of the pronounced plate fogging that occurs in water-based ink gravure printing.

**[0045]** The hardness of the plate surface is a Vickers hardness of 1000 to 1100 when it is a hard chrome plating. Therefore, it is preferable for the undercoat 3b to be softer than the plate surface. The reason for this is that since the undercoat 3b also rubs on the plate surface, either a material that is hard but has a low coefficient of friction must be selected as the undercoat 3b or a material that is softer than the plate surface must be selected in order to minimize the wear of the plate surface.

**[0046]** From this standpoint, a favorable material for the undercoat 3b is a ceramic composite nickel plating. This plating involves an addition of a suitable amount of one or more types of ceramic micro-powder selected as needed from the group of silicon carbide, boron nitride, and various other such ceramic micro-powders to an electroless nickel bath or an electro-nickel bath; and the plating is performed under agitation. As a result, a nickel plating is applied, and simultaneously the above-described micro-powder precipitates inside the plating film. This plating may be baked if necessary.

**[0047]** The undercoat 3b may also be formed by hard nickel plating or soft chrome plating. Alternatively, it may be formed from a silicon nitride ceramic, zirconia, or the like; and alumina may also be flame sprayed.

**[0048]** The undercoat 3b is applied to at least one or both sides of the knife edge of the core 3a. The undercoat 3b is formed in a thickness of approximately 5 to 10  $\mu\text{m}$ . The thickness can vary depending upon the type of undercoat to be used. When alumina is applied by flame spraying, it can be formed on just one side, which is on the ink scraping side, of the knife edge of the core 3a.

**[0049]** The doctor blade 3 shown in Figure 1 has no undercoat 3b, and there is no wear strength enhancement for the core 3a. Thus, this doctor blade wears faster than the doctor blade 3 shown in Figure 2.

**[0050]** The diamond-like carbon coating 3c is a coating of an amorphous carbon compound formed in a thickness of 0.1 to 5  $\mu\text{m}$  by a thin film formation technique carried out under a vacuum on both sides of the core 3a which has been coated with the undercoat 3b.

**[0051]** The diamond-like carbon coating 3c has outstanding characteristics. It is even harder and has greater wear resistance than ceramics that are considered to be hard, yet is not brittle like a ceramic, having an extremely low Young's modulus and good flexibility as a coating. Furthermore, the surface is smooth and the coefficient of friction is low ( $\mu = 0.12$ ), providing good slip properties. The surface energy is extremely low and very little frictional heat is generated; and there is no danger of seizure occurring.

**[0052]** The diamond-like carbon coating 3c may be formed by vapor deposition, sputtering, ion plating or vapor phase epitaxy.

**[0053]** The surface roughness of the diamond-like carbon coating is shown as  $R_a = 7.3$  angstroms, and the surface roughness of a TiN film, which is considered to be a hard film, is shown as  $R_a = 113$  angstroms.

**[0054]** The diamond-like carbon coating 3c has far better surface smoothness, hardness, and wear resistance than quenched carbon steel or stainless steel.

**[0055]** The coefficient of friction of the diamond-like carbon coating is extremely low, being only about one-quarter of the coefficient of friction of a TiN film, CrN film, TiCN film, or cemented carbide, 411 of which are considered hard films; and the coefficient of friction is even lower compared to quenched carbon steel.

**[0056]** The hardness of the diamond-like carbon coating varies depending upon the material on which the coating is to be formed, but it is said the hardness is to be a Vickers hardness of about 500 when the coating is formed on silicone rubber, and about 2000 to 3000 when the coating is formed on titanium steel.

**[0057]** The tests indicate that when the diamond-like carbon coating 3c was formed on carbon steel and filed with a file that has a Vickers hardness of 950, the file left no marks whatsoever. This coating was further measured by micro-hardness tester and found to be

harder than a ceramic doctor.

**[0058]** The reason to form the diamond-like carbon coating 3c in the present invention so as to cover both sides of the knife edge of the doctor blade 3 is to enhance the wear resistance of the doctor blade, to prevent the pronounced plate fogging from occurring in water-based ink gravure printing, and to minimize the wear of the plate surface.

**[0059]** Generally, for water-based ink gravure printing to be made practical, various improvements are needed. It is necessary to increase the precision of plate images and shorten the time it takes for water evaporation by switching the number of screen lines from 175 lines per centimeter to 300 lines per centimeter. It is also necessary to reduce the wear of the doctor blade and of the plate surface and to use a water-based ink that is not prone to plate fogging. In addition, such attempts at practical application of water-based ink gravure printing are premised by accomplishing a mirror surface so as to make the roughness on the plate surface as low as possible after the plate is formed and chrome is plated.

**[0060]** Polishing the plate surface into a mirror finish means that virtually none of the ink will pass under the doctor blade, and it also means that the self-lubricity of the plate surface will be kept low. It is expected that the coefficient of friction between the doctor blade and the plate surface will be higher, and the wear of both the doctor blade and the plate surface will be faster.

**[0061]** However, the doctor blade shown in Figure 1 comprises the core 3a covered with the diamond-like carbon coating 3c; and the doctor blade shown in Figure 2 comprises the core 3a coated with the undercoat 3b so as to increase the hardness of the core 3a, and the undercoat 3b is further covered with the diamond-like carbon coating 3c.

**[0062]** The diamond-like carbon coating 3c bears the majority of the frictional force, and the diamond-like carbon coating has extremely high wear resistance as well as an extremely low coefficient of friction (about one-quarter of the coefficient of friction of a TiN film, CrN film, TiCN film, or cemented carbide), while the frictional force to which the end face at the knife edge of the undercoat and the core (which have a higher coefficient of friction) are subjected is kept low. Accordingly, the coefficient of friction can be kept low for the doctor blade as a whole.

**[0063]** The force at which the doctor blade presses on the plate surface has a pressure distribution such that the force is greater on the ink scraping side and decreases toward the back side. Also, the end face at the knife edge of the undercoat 3b and the core 3a has a high coefficient of friction, but since the surface area of contact with the plate surface is far greater than that of the diamond-like carbon coating 3c, the pressure per unit of surface area is far lower than that of the diamond-like carbon coating 3c, and this end face therefore contributes very little to the wearing down of the plate surface.

**[0064]** This means that the diamond-like carbon coat-

ing 3c, which has a greater pressure per unit of surface area, contributes more to the wearing down of the plate surface; and the contribution of the diamond-like carbon coating 3c on the ink scraping side is particularly great. However, the diamond-like carbon coating 3c has outstanding characteristics. It has extremely high hardness and wear resistance, its surface is extremely smooth, it has good slip properties because its coefficient of friction is only 0.12, and its surface energy is extremely low and very little frictional heat is generated; thus, there is no danger of seizure occurring. Accordingly, this diamond-like carbon coating contributes to the wearing down of the plate surface sufficiently less than in the past.

**[0065]** Because the diamond-like carbon coating 3c on the ink scraping side has extremely high wear resistance and does not readily wear down, the end face at the knife edge of the undercoat 3b and core 3a, does not readily wear down, either. The end face at the knife edge of the undercoat 3b and core 3a is softer and has less wear resistance than the diamond-like carbon coating 3c; thus it wears down along with the diamond-like carbon coating 3c on the ink scraping side. If the diamond-like carbon coating 3c wears down, the end face at the knife edge of the undercoat 3b and the core 3a, cannot remain exposed.

**[0066]** The diamond-like carbon coating 3c on the back side effectively inhibits the wearing down of the end face at the knife edge of the undercoat 3b and the core 3a.

**[0067]** If the undercoat 3b consists of a hard and brittle ceramic, the diamond-like carbon coating 3c that overcoats the undercoat 3b prevents cracks from developing in this ceramic.

**[0068]** Therefore, in the doctor blade of the present invention, the coefficient of friction between the doctor blade and the plate surface that has been polished to a mirror finish is avoided from increasing, and the diamond-like carbon coating has extremely high wear resistance. Accordingly, the knife edge of the doctor blade can continue indefinitely to remove the ink even when the printing is carried out at a practical printing speed and for an extended printing length.

**[0069]** Furthermore, with the doctor blade 3 of the present invention, the diamond-like carbon coating 3c slides over the plate surface, fills the cells with ink and scrapes off any excess ink. Because of its very smooth surface and its extremely low Young's modulus, the diamond-like carbon coating 3c can continue indefinitely to remove the ink very well.

**[0070]** The diamond-like carbon coating 3c has an extremely low Young's modulus and is elastic, unlike a ceramic or TiN, CrN, TiCN, or the like. Accordingly, the portion in contact with the plate surface deforms, albeit slightly, as it slides, and as a result the coefficient of friction is extremely low (0.12) and the wear of the plate surface can be kept to a minimum. Furthermore, because the diamond-like carbon coating 3c has low sur-

face energy, very little heat is generated by friction, and there is no danger of seizure occurring.

**[0071]** In use of the doctor blade with a diamond-like carbon coating, the smoothness and linearity of the knife edge are high, the wettability is good, the hardness is high, the Young's modulus is low, and the film is flexible. Accordingly, the doctor blade slides easily over the plate surface. In particular, because of its elasticity, the doctor blade tends to get very close to the water-based ink tying in the sandpaper marks formed in the non-printing area of the plate surface; and since an extremely small amount of ink goes under the, doctor blade, the wear resistance is high, and good ink removal by the knife edge of the doctor blade is maintained indefinitely, All of this effectively avoid plate fogging; and no plate fogging occurs even when the printing is curled out at a practical printing speed and for an extended printing length.

**[0072]** Meanwhile, being able to minimize the wear of the plate surface allows roughening of the surface of the non-printing area over time during printing to be suppressed, which is an effective means for preventing plate fogging.

**[0073]** To the contrary, a ceramic doctor blade has a large coefficient of friction and causes plate fogging due to greater wear of the plate surface.

**[0074]** The doctor blade 3 of the present invention has both sides of a quenched carbon steel knife edge or a stainless steel knife edge that is covered with the diamond-like carbon coating. This gives it better wear resistance than that of a ceramic, and it therefore has a longer service life, There is no danger of the blade chipping or doctor streaking, Thus, the doctor blade has higher reliability.

**[0075]** A ceramic doctor blade also has low wear and a long service life, but it is susceptible to blade chipping and doctor streaking.

## EXAMPLES

**[0076]** (1) Gravure printing was performed using a water-based ink, and the proper printing speed at which no plate fogging was observed was examined.

**[0077]** A core of quenched carbon steel with a thickness of 150  $\mu\text{m}$  was coated with a diamond-like carbon coating in a thickness of 4  $\mu\text{m}$  to produce a doctor blade of the embodiment shown in Figure 1. Its doctor blade was tested, No plate fogging occurred at a practical printing speed of 110 to 130 m/min, which is the same speed as in oil-based ink gravure printing.

**[0078]** Also, both sides of a core of quenched carbon steel with a thickness of 150  $\mu\text{m}$  were coated with an undercoat composed of a ceramic composite nickel plating with a thickness of 10  $\mu\text{m}$ , and this was overcoated with a diamond-like carbon coating in a thickness of 4  $\mu\text{m}$ , thus producing a doctor blade of the embodiment shown in Figure 2. This doctor blade was tested. No plate fogging occurred at a practical printing speed of 110 to 130 m/min, which is the same speed as in oil-

based ink gravure printing.

**[0079]** Furthermore, an undercoat with a thickness of 10  $\mu\text{m}$  was formed by flame spraying on the ink scraping side of a core of quenched carbon steel with a thickness of 150  $\mu\text{m}$ , and both sides of this were over-coated with a diamond-like carbon coating in a thickness of 4  $\mu\text{m}$  to produce a doctor blade of the embodiment shown in Figure 2. This doctor blade was tested. No plate fogging occurred at a practical printing speed of 110 to 130 m/min. which is the same speed as in oil-based ink gravure printing. Printing was continued with this doctor blade for 100,000 meters, but still no doctor streaks or whiskers were observed.

**[0080]** In contrast, with a conventional doctor blade made of a very thin strip of steel, plate fogging was observed at a printing speed of 95 m/min. Plate fogging was also observed at about the same printing speed with a ceramic doctor blade, and doctor streaks occurred after an extended printing run.

**[0081]** (2) The doctor blade of the embodiment shown in Figure 1 and described in (1) above was installed in a doctor apparatus, and water-based ink gravure printing was performed (the water-based ink was Aquapia White (trade name; contains titanium white) made by Toyo Ink, Inc.). After printing for 28,000 meters, the amount of wear on the knife edge of the doctor blade was measured and found to be 187  $\mu\text{m}$ . This was a proportion of 67  $\mu\text{m}$  of wear for every 10,000 meters of printing.

**[0082]** Also, the doctor blade of embodiment shown in Figure 2 and described in (1) above was installed in a doctor apparatus, and water-based ink gravure printing was performed (the water-based ink was Aquapia White (trade name; contains titanium white) made by Toyo Ink Inc.). After printing for 28,000 meters, the amount of wear on the knife edge was measured and found to be 86  $\mu\text{m}$ . This was a proportion of 30  $\mu\text{m}$ . of wear for every 10, 000 meters of printing.

**[0083]** In contrast, water-based ink gravure printing was performed with a conventional doctor blade made of a very thin strip of steel, and the amount of wear on the. knife edge was measured after printing 20,000 meters. The result was that wear was 660  $\mu\text{m}$ . This was a proportion of 330  $\mu\text{m}$  of wear for every 10,000 meters of printing.

**[0084]** It was also revealed that pronounced plate fogging will appear with water-based ink gravure printing if the knife edge of the doctor blade wears down and recedes from the roller just as with oil-based ink gravure printing.

**[0085]** (3) The doctor blade of the present invention described in (1) above was installed in a doctor apparatus, and water-based ink gravure printing was performed (the water-based ink was Aqua Ecole (trade name made by Toyo Ink, Inc.). The amount of wear on the plate surface after printing for 50,000 meters was measured, the printing roller had worn down 2  $\mu\text{m}$  in the printing area and 0 to 1  $\mu\text{m}$  in the non-printing area. The

results were more or less the same when the doctor blade according to the embodiment shown in Figure 2 and described in (1) above was used.

**[0086]** In contrast, water-based ink gravure printing was performed with a conventional doctor blade made of a very thin strip of steel, and the amount of wear on the plate surface after the same printing for 50,000 meters was measured. The printing roller had worn down by 4  $\mu\text{m}$  in the printing area and 2  $\mu\text{m}$  in the non-printing area

**[0087]** (4) A diamond-like carbon coating was produced by plasma CVD for the doctor blade of the present invention, and the annealing hardness was measured. The temperature during the production of the diamond-like carbon coating by thermolabeling was 210°C on the inner surface of the film and 200°C on the outer surface. In contrast since the quenching temperature of the blade core 3a composed of carbon steel was over 300°C, the blade core 3a was not annealed by the heating during film formation, the hardness was maintained at a Vickers hardness of 600, and the blade core 3a did not end up having a hardness that is too low for the support of the diamond-like carbon coating.

**[0088]** (5) The relationship between the roughness of the plate surface of a printing roller, the wettability of the plate surface, and plate fogging was examined; and it was revealed that the greater the roughness of the plate surface, the lower the apparent wettability, the greater the contact angle of liquid drops, and the more pronounced is plate fogging. Coincidentally, it was confirmed that a diamond-like carbon coating has an extremely smooth surface, and it has a smaller contact angle and better wettability than either carbon steel, nickel, or ceramic.

**[0089]** As described above, according to the doctor blade of the present invention shown in Figure 1, the core 3a composed of carbon steel or stainless steel is coated with the diamond-like carbon coating 3c; and according to the doctor blade of the present invention shown in Figure 2, the core 3a composed of carbon steel or stainless steel is coated on one or both sides thereof with the undercoat 3b that is harder than the core 3a and then over-coated with the diamond-like carbon coating 3c. As a result, a self-lubricating function and a wear resistance are ensured for a doctor blade whose distal end is abutted against a gravure printing roller to scrape off any excess ink. Thus, a longer service life is assured for a doctor blade, and there is no danger of the plate surface being scratched.

**[0090]** The doctor blade shown in Figure 2 has a longer service life than the doctor blade shown in Figure 1 because the hardness of the core 3a is increased by the undercoat 3b.

**[0091]** According to the doctor blade of the present invention, no plate fogging occurs in water-based ink gravure printing even when the printing is carried out at a practical printing speed and for a practical printing length (the number of printed sheets). Also, with the doc-

tor blade having the diamond-like carbon coating thereon, since the knife edge of the doctor blade has good smoothness and linearity, high wettability, and a flexibility on the surface, the knife edge stays close to the water-based ink lying in the sandpaper marks formed in the non-printing area of the plate surface, and the amount of ink that goes under the doctor blade is markedly reduced. Thus, plate fogging can be effectively avoided.

**[0092]** Plate fogging used to occur in conventional water-based ink gravure printing when the printing speed is raised to a practical level. However, with the doctor blade of the present invention, even when it is used with low surface roughness printing plates and higher precision plate images, water-based ink gravure printing is commercially feasible for the first time.

**[0093]** With the doctor blade shown in Figure 1, because the wear of the knife edge which ensures the ink scraping function is only about one-fifth that of a conventional product, the service life of the doctor blade extends to five times that of the conventional product. With the doctor blade shown in Figure 2, because the wear of the knife edge which ensures the ink scraping function is only about one-tenth that of a conventional product, the service life of the doctor blade extends to ten times that of the conventional product. Thus, plate fogging can be prevented for an extended period of time. Maintenance is also easier because the doctor blade of the present invention does not need to be replaced so often.

**[0094]** In addition, with the doctor blade of the present invention, since wear of the plate surface can be kept to a minimum, the number of sheets that can be printed by the plate surface can be substantially increased to at least double; and chrome replating only needs to be performed half as frequently.

## Claims

1. A doctor blade having a distal end thereof to be abutted against a gravure printing roller so as to fill cells with ink and scrape off any excess ink, wherein said doctor blade comprises:

a metal core which is formed from a thin stainless steel sheet or a thin carbon steel sheet that is quench hardened, a distal end of said metal core having a knife edge, and  
a diamond-like carbon coating that at least coats both sides of said distal end of said metal core.

2. A doctor blade having a distal end thereof to be abutted against a gravure printing roller so as to fill cells with ink and scrape off any excess ink, wherein said doctor blade comprises:

a metal core formed from a thin stainless steel sheet or a thin carbon steel sheet that is quench



hardened, a distal end of said metal core having  
a knife edge;  
an undercoat which at least coats one or both  
sides of the distal end of said core and is harder  
than the metal core and softer than a diamond-  
like carbon coating and which increases hard-  
ness of the metal core, and  
a diamond-like carbon coating that over-coats  
at least both sides of the distal end of said metal  
core.

3. A doctor blade with one edge thereof to be abutted  
against a gravure printing roller so as to fill cells in  
a surface of said gravure printing roller with ink and  
scrape off any excess ink from said cells, wherein  
said doctor blade comprises:

a metal core of a plate shape having a prede-  
termined thickness, said metal core being  
quench hardened and a thickness thereof be-  
ing decreased toward at least one edge thereof;  
and  
a diamond-like carbon coating which is coated  
at least on said one edge,

4. The doctor blade according to claim 3, wherein said  
metal core is formed from a thin stainless steel  
sheet.
5. The doctor blade according to claim 3, wherein said  
metal core is formed from a thin carbon steel sheet.
6. The doctor blade according to claim 3, further com-  
prising an undercoat layer provided between said  
metal core and said diamond-like carbon coating,  
said undercoat layer being harder than said metal  
core and softer than said diamond-like carbon coat-  
ing,

FIG 1

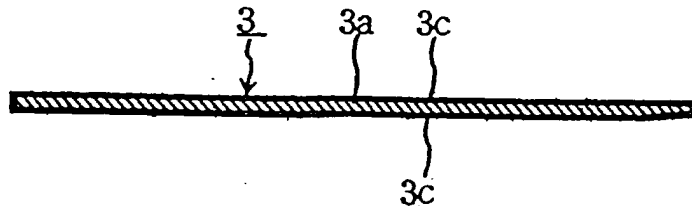


FIG 2

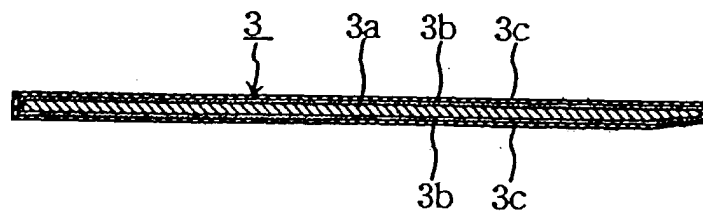
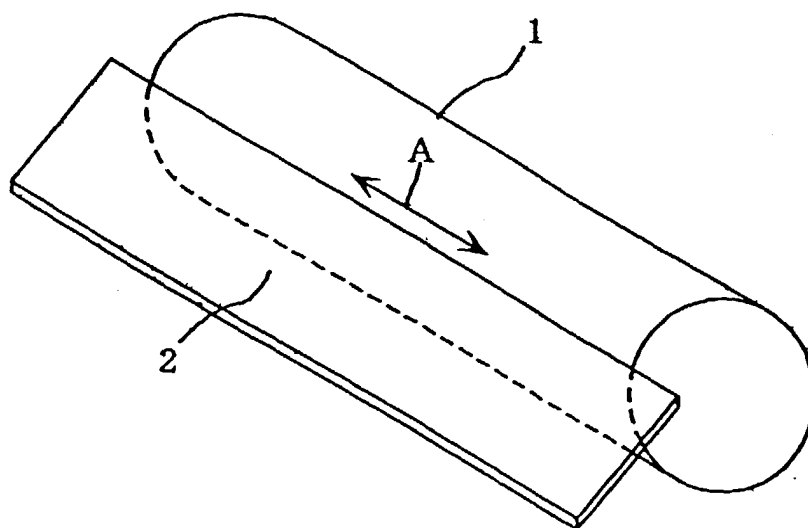


FIG 3





European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 99 30 8050

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