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DIFFERENTIAL SPEED GRAVURE COATING PROCESS

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FIG. 1

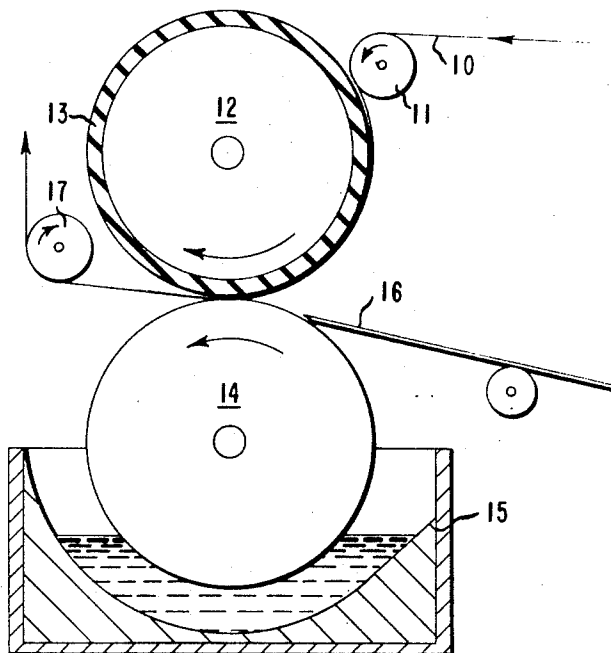
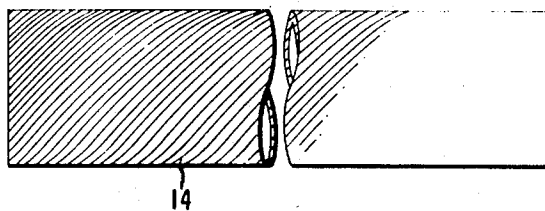


FIG. 2



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DIFFERENTIAL SPEED GRAVURE COATING PROCESS

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8 Claims

ABSTRACT OF THE DISCLOSURE

An improved coating process using a gravure roll in which replication of the gravure pattern is eliminated by rotating the roll at a surface velocity of 1.8–10 times the linear speed of the web being coated. The process is useful in making magnetic recording tape, photographic film and moisture-proof coatings.

This invention relates to a process for uniformly coating various coating fluids onto a flexible web or support. More particularly, this invention relates to coating a flexible web by means of a gravure or intaglio coating cylinder while maintaining a speed differential between the cylinder and the web on which the coating is made.

Uniform coatings across the breadth of a web and along the length of a web are desired in many fields of technology. In the past, there has been a serious problem in obtaining the desired uniformity of coating thickness in such coatings. The problem has taken various forms, such as side-to-center variations in coating thickness, front-to-end variations in coating thickness, and local up-and-down variations in coating thickness (over a relatively small distance). Many types of coating techniques have been utilized in an effort to improve uniformity of coating thickness. These include: skim coating, roller coating, reverse-roller coating, air-knife coating, extrusion coating and gravure coating, to mention a few. Each of these techniques generally presents certain coating problems which affect the quality of the ultimate coating. The skim coating technique is very slow and often causes bubble streaks and side-to-center non-uniformity of coating thickness. Air knife coating is also rather slow and frequently causes a surface "skin" to form on the coating solution which can be transferred to the coating. The reverse roll coating procedure presents difficulties in forming uniform thin coatings since there are eccentric irregularities between the surfaces of the machined rolls. Extrusion coating is complicated in operation and often results in air being trapped between the base and coating.

For many coating fluids, gravure coating has been found to be superior as regards uniformity of coating thickness, particularly across the web and in the machine direction. However, a serious difficulty posed by the direct impression gravure coating has been a tendency to transfer to the coating web a replication of the groove or dot pattern found in the gravure cylinder. This can be thought of as a micro "hill and valley" pattern and is clearly visible on viewing most gravure-coated webs under proper conditions of illumination. It will be recognized that the gravure method does have inherent advantages in over-all control of the amount of coating fluid transferred to the web. This is because the etched or engraved grooves or dots of the gravure cylinder can be machined or controlled to extremely fine tolerances. Thus, they contain a controlled and uniform amount of coating fluid across the breadth of the gravure cylinder as a result of doctor blade action. If these grooves or dots then transfer a uniform proportion of this fluid to the web, at each contact with the web they will, theoretically, put down a uniform coat-

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ing of fluid both across the width and down the length of the web. However, in actual practice, a slight "hill and valley" effect is produced throughout the coating. In addition, the standard gravure coating process is inflexible since a new cylinder must be employed for each different coating thickness.

The improved gravure coating process of this invention essentially eliminates the undesirable coating effects of forming minute ridges on the coating surface. This novel process comprises (a) passing a flexible web between the nip formed by a gravure cylinder and a back-up roll where the surface velocity of said gravure cylinder is at least about 1.8 times the velocity of said web and the nip force is about 2 to 60 lbs. per inch of nip width, and (b) coating the web as it passes the nip with a fluid carried by the gravure cylinder, said fluid having a Brookfield viscosity of about 0.2 to 20 poises measured with a #4 spindle at 50 r.p.m. The nip pressure best suited for a particular web is easily determined empirically, the primary consideration being the effect on a web of a specified nip pressure since the gravure roll is travelling faster than the web and too high a pressure may result in web damage or chatter whereas too little pressure will cause coating skips. In the preferred process of this invention, a ferromagnetic chromium dioxide dispersion having a Brookfield viscosity of about 7 to 15 poises is coated on a polyester support having a thickness of about .001 to .0015 inch while the nip force is maintained from about 2 to 15 lbs. per inch of nip width and the differential of cylinder speed to web speed is about 2.0–10 to 1.

The invention will be illustrated by reference to the drawing wherein:

FIGURE 1 represents a view of the nip formed by the rolls.

FIGURE 2 represents a typical gravure coating roll.

Referring to FIGURE 1 the web 10 is passed over a follow roll 11 which places the web in contact with the surface 13 of the back-up roll 12. The surface 13 is an elastomeric material which accommodates web thickness variations, conforms the web to the cylinder surface and provides traction to the web and, consequently, drives the web toward the nip. This material conveniently has a Shore A durometer hardness of about 20–90. The gravure cylinder 14 is rotating in the same direction as the web; however, the cylinder and the back-up roll have independent drive means to maintain the required speed differential. The gravure cylinder revolves in a pan 15 containing the required coating fluid. This fluid fills the grooves in the cylinder and excess fluid is kept from entering the nip area by the doctor blade 16. After the web passes through the nip it is removed over a take-off roll 17 and, subsequently, dried. FIGURE 2 shows a standard gravure cylinder with the grooves set at 45° which may be used as cylinder 14 of FIGURE 1.

In the process of this invention there are three critical areas where controls should be applied. These critical areas are:

(1) The differential surface speed of the gravure coating cylinder vs. the speed of the web.

(2) The viscosity of the coating fluid.

(3) The force between gravure cylinder and back-up roll, known as the nip force.

There are many other variables which are common in any gravure coating process known to the art. Some of these variables are listed below; however, in the differential speed gravure coating process of this invention, control of these variables is essentially no more critical than in conventional gravure coating and as such their control is well within the skill of the art.

These latter generally critical variables include: gravure cylinder pattern; attraction of the coating fluid to the

web; plasticity and resilience of the support; support thickness; back-up roll hardness; doctor blade pressure; doctor blade angle; take-off roll angle; and rheological properties of the coating fluid (other than viscosity).

The above variables must be specified correctly in order to make a good quality conventional gravure coating. Many of them are dependent upon each other. However, the three listed earlier represent those that require setting at values different from those normally encountered for standard gravure coating, when practicing differential speed gravure coating.

The flexible supports used as the coating base of this invention may be selected from a wide variety of web materials. These materials include paper, cloth and plastic sheet material. For example, the cellulosic supports, e.g., cellulose acetate, cellulose triacetate, etc., may be used as well as polymerized vinyl compounds, e.g., copolymerized vinyl acetate and vinyl chloride. Also the polyolefins such as polyethylene and polypropylene may be used. The polyesterification product of a dicarboxylic acid and a dihydric alcohol such as those made according to the teachings of Alles, U.S. Patent 2,779,684 form good supports. The preferred supports are the polymeric terephthalate ester films of less than .005 inch thickness prepared by Alles, U.S. Patent 3,165,499, issued Jan. 12, 1965, and the patents referred to therein.

The coating materials utilized in the process of this invention are primarily limited only by their Brookfield viscosities which must fall within the stated viscosity limits. Among the useful coating materials are dispersions of chromium dioxide for use in the production of magnetic tapes, light-sensitive silver halide solutions for the production of photographic films and moisture proof coatings for the supports.

The following procedures and examples are illustrative of the invention; however, the invention is not intended to be limited to these examples.

Procedure A

A coating dispersion is prepared by milling 1523 grams of ferromagnetic CrO_2 prepared as described in the U.S. application of Cox, Ser. No. 414,058, filed Nov. 27, 1964 (U.S.P. 3,278,263, Oct. 11, 1966); 61 grams of a soya lecithin; 2305 grams of tetrahydrofuran (THF); 1631 grams of a 15% by weight THF solution of the polyester-

urethane disclosed in column 4, lines 12-27 of U.S. Patent 2,871,218; 815 grams of a 30% by weight solution of "Saran" F220, a vinylidene chloride/acrylonitrile copolymer having an average molecular weight of about 10,000 in methyl isobutyl ketone (MIBK). This dispersion is milled for a day and the viscosity is then adjusted to 12-14 poises with THF. The dispersion is milled for several days. Then 450 cc. of THF is added and the dispersion is milled for 16 additional hours. Then 4.6 grams of stearamide, 15.0 grams of n-amyl alcohol and enough THF is added to give a total solution viscosity of 7.5 to 8 poises and the mixture is milled an additional 24 hours. The complete mixture is again milled for at least one hour after the addition of 65.0 grams of a 60% MIBK solu-

tion of a cross-linking agent prepared by reacting 2.95 mols of toluene diisocyanate with 1 mol of trimethylolpropane.

Procedure B

A medium speed, aqueous gelatino silver bromiodide emulsion in which the silver halides were composed of 1.2 mol percent silver iodide and 98.8 mol percent silver bromide is prepared and washed as described in Moede U.S. Patent 2,772,165 using a water-soluble partial acetal of polyvinyl alcohol and o-sulfobenzaldehyde. After washing, additional gelatin was added to bring the gelatin/silver halide ratio to 1:1. The concentration of the emulsion was adjusted by addition of water so that it contained 8.6% silver halide based on the total weight of the emulsion ready for coating.

Example 1

A continuous length of 1.0 mil thick biaxially oriented polyethylene terephthalate film is gravure coated by the differential speed technique shown in FIGURE 1 using the magnetic chromium dioxide dispersion described in Procedure A as the coating fluid, said dispersion having a viscosity of 11.2 poises measured with a #4 spindle at 50 r.p.m. on a Brookfield viscometer. The gravure cylinder has a uniform grooved pattern of 50 lines per inch. The grooves are triangular in cross-section and at a 45° angle with respect to the rotating axis of the gravure cylinder. The back-up roll has a steel core with an elastomeric covering having a hardness of 40 durometer as measured on the Shore A scale. The nip pressure between the back-up roll and gravure cylinder is maintained at 15 lbs. per inch of width. The doctor blade is set at an angle of 30 degrees with the line of tangency at the point of contact with the gravure cylinder; the distance between the line of doctoring and the coater nip is maintained at ½ radian. The doctor blade is loaded to maintain a force of contact of 8.6 lbs. per inch with the gravure cylinder. The web speed is set at 63 ft. per minute and the surface speed of the gravure cylinder is controlled at 239.4 ft. per minute to obtain a differential speed ratio of 3.8. With these conditions, a long length coating having excellent physical coating quality and uniformity is obtained and is characterized by the absence of any replication of the gravure cylinder's pattern. The dry coated thickness is 0.180 mil.

EXAMPLES 2, 3, 4 AND 5

Example	Differential Speed Ratio	Web Speed Ft./min.	Nip Pressure, lbs./inch width	Brookfield Viscosity (poises)	Web Thickness in mils	Doctor Blade Pressure, lbs./inch width	Dry Coating Thickness in mils
2-----	2.07	97	2.2	10.4	1.5	13.2	0.170
3-----	3.08	65	2.2	10.4	1.5	14.8	0.250
4-----	4.10	49	2.2	10.4	1.5	16.3	0.320
5-----	6.5	31	10.6	10.8	1.0	16.3	0.360

In Examples 2, 3 and 4, a gravure cylinder of 50 lines per inch is employed; the back-up roll has an elastomeric covering of hardness 40 durometer (Shore A scale); the coating fluid is formulated as described in Procedure A. The doctor knife angle and point of contact are the same as in Example 1.

In Example 5, a gravure cylinder of 45 lines per inch is employed; the back-up roll, doctor knife angle and point of contact are the same as in Example 1. With these conditions, a long-length coating having excellent physical coating quality and thickness uniformity is obtained and is characterized by the absence of any replication of the gravure cylinder pattern. The coating fluid is formulated as described in Procedure A.

EXAMPLES 6, 7 AND 8

Example	Differential Speed Ratio	Web Speed Ft./min.	Nip Pressure, lbs./inch width	Brookfield Viscosity (poises)	Web Thickness in mils	Doctor Blade Pressure, lbs./inch width	Dry Coating Thickness in mils
6-----	2.01	100	2.2	10.0	1.0	11.7	0.080
7-----	2.01	100	8.4	10.0	1.0	11.7	0.080
8-----	2.18	45	17.3	15.0	1.0	7.1	0.150

In Examples 6 and 7 above, a gravure cylinder having 110 lines/inch is used; in Example 8 a 50 line/inch cylinder is used; the back-up roll and coating fluid are the same as in Example 1. With these conditions, a long-length coating having excellent physical coating quality and thickness uniformity is obtained and is characterized by the absence of any replication of the gravure cylinder pattern.

EXAMPLES 9, 10 AND 11

Example	Differential Speed Ratio	Web Speed Ft./min.	Nip Pressure, lbs./inch width	Brookfield Viscosity (poises)	Web Thickness in mils	Doctor Blade Pressure, lbs./inch width	Dry Coating Thickness in mils
9.....	3.08	65	15.0	17.0	1.0	8.6	0.190
10.....	3.06	65	15.0	10.0	1.0	10.2	0.190
11.....	2.56	78	5.0	8.0	1.0	9.9	0.120

In Examples 9 and 10, a 50 line/inch gravure cylinder is used; in Example 11, a 120 line/inch cylinder is used. In Examples 9, 10 and 11 the back-up roll, doctor knife angle and point of contact for the doctor knife are the same as in Example 1. With these conditions, a long-length coating having excellent physical coating quality and thickness uniformity is obtained and is characterized by the absence of any replication of the gravure cylinder pattern. The coating fluids in these examples are prepared as in Procedure A with the exception that the fluids in Examples 9 and 11 are modified by varying the THF content to provide the viscosity shown.

EXAMPLES 12 AND 13

Example	Differential Speed Ratio	Web Speed Ft./min.	Nip Pressure, lbs./inch width	Brookfield Viscosity (poises)	Web Thickness in mils	Doctor Blade Pressure, lbs./inch width	Dry Coating Thickness in mils
12.....	1.96	49	15.1	11.0	1.0	7.1	0.100
13.....	4.7	17	12.9	11.0	1.0	7.1	0.230

In Examples 12 and 13, a 50 line/inch gravure cylinder is used; the back-up roll, doctor knife angle and point of contact for the doctor knife are the same as in Example 1. The coating fluid employed is a solution of 28 parts by weight of "Saran" F220) a vinylidene chloride/acrylonitrile copolymer of average molecular weight about 10,000) in 72 parts by weight of methyl isobutyl ketone. A coating having excellent physical coating quality and thickness uniformity is obtained and is characterized by the absence of any replication of the gravure cylinder pattern.

EXAMPLE 14

Example	Differential Speed Ratio	Web Speed Ft./min.	Nip Pressure, lbs./inch width	Brookfield Viscosity (poises)	Web Thickness in mils	Doctor Blade Pressure, lbs./inch width	Dry Coating Thickness in mils
14.....	3.0	10	25	0.4	1.0	2.4	0.070

In Example 14, a 50 line/inch gravure cylinder is used. The back-up roll, doctor knife angle and point of contact are the same as Example 1. The coating fluid is an aqueous silver iodo-bromide/gelatin emulsion as described in Procedure B. The resulting coating is smooth and characterized by the absence of any replication of the gravure cylinder pattern.

The process of this invention has been found to be adaptable for coating a variety of compositions such as coatings for magnetic tapes and coatings of photographic emulsions. The web speeds utilized during this improved process can be the same as those used in the standard gravure coating process which can be more than 500 feet per minute. The differential speed between the gravure cylinder and web speed must be greater than 1:1. In gen-

eral, good smooth coatings may be obtained using fine lined cylinders, i.e., 200 lines per inch, at lower speed differentials, i.e., 1.1:1.

A distinct advantage of the process of this invention is its ability to operate at lower nip pressures than previously used for coating the same base and composition by the prior art gravure process. A further advantage is the ability to change coating thicknesses by varying the dif-

ferential ratio instead of having to change the entire gravure cylinder. This novel process will give good dry thickness coatings within the range of about 0.005 to 0.8 mil. Generally, the preferred coatings prepared by this process have a dry coating thickness of about 0.1 to 0.3 mil. A still further advantage of this invention is the ability to obtain higher coating densities than obtained by other coating techniques which is of great importance in producing magnetic tapes.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A process for coating a flexible web which comprises:

- passing said flexible web between the nip formed by a gravure cylinder and a back-up roll wherein the surface velocity of said gravure cylinder is at least 1.8 times greater than the web velocity and the nip force is 2 to 60 lbs. per inch, the surface of the cylinder moving in the same direction as the web, and
- coating the web as it passes through said nip with a fluid carried by said gravure cylinder, said fluid having a Brookfield viscosity of 0.2 to 20 poises.

2. A process as described in claim 1 where the surface velocity of said gravure cylinder is 1.8 to 10 times the velocity of said web.

3. A process as described in claim 1 where said nip force is 2 to 20 lbs. per inch.

4. A process as described in claim 1 where said fluid has a Brookfield viscosity of 7 to 15 poises.

5. A process for coating a flexible plastic web having a thickness of no greater than 5 mils which process comprises:

- passing said web between the nip formed by a gravure cylinder and a back-up roll wherein the surface velocity of said gravure cylinder is 1.8 to 10 times the velocity of said web and the nip force is

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2 to 20 lbs. per inch, the surface of the cylinder moving in the same direction as the web, and

(b) coating the web as it passes through said nip with a fluid carried by said gravure cylinder, said fluid having a Brookfield viscosity of 0.2 to 20 poises.

6. A process as described in claim 5 where said fluid consists of a ferromagnetic chromium dioxide dispersion.

7. A process as described in claim 5 where said coating step (b) gives a dry coating thickness of 0.005 to 0.8 mil.

8. A process as described in claim 5 where said fluid has a Brookfield viscosity of 7 to 15 poises.

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