United States Patent [19]

Gunning

[11] **3,908,044**

[45] **Sept. 23, 1975**

[54] **APPARATUS AND METHOD FOR COATING A WEB**

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[73] Assignee: **Abitibi Paper Company Ltd.**, Toronto, Canada

[22] Filed: **Nov. 15, 1973**

[21] Appl. No.: **416,105**

Related U.S. Application Data

[63] Continuation of Ser. No. 187,785, Oct. 8, 1971, abandoned.

[30] **Foreign Application Priority Data**

Oct. 13, 1971 Canada 95355

[52] **U.S. Cl.** **427/209;** 118/404; 118/405; 427/434; 427/439

[51] **Int. Cl.²**..... **B05C 9/04;** B05C 3/02; B05C 3/12

[58] **Field of Search** ..... 117/113, 115, 111 H, 68; 118/404, 405; 427/209, 434, 439

[56] **References Cited**

UNITED STATES PATENTS

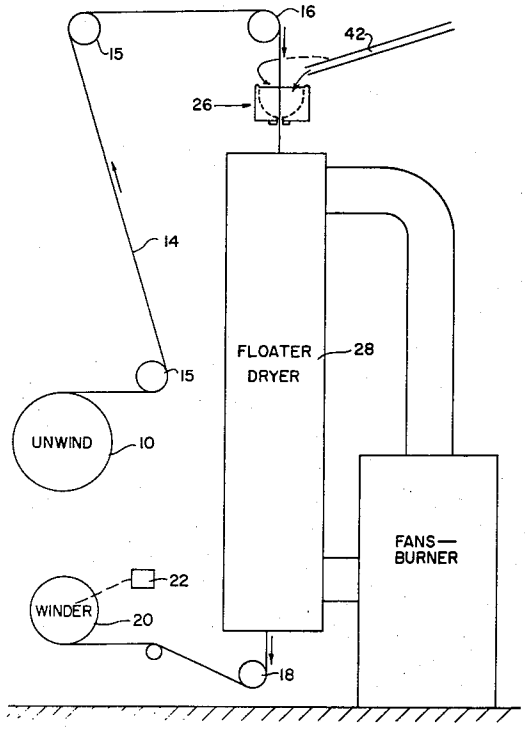
2,766,721 10/1956 Paquette ..... 118/413 X

Primary Examiner—Michael R. Lusignan
Attorney, Agent, or Firm—Spencer & Kaye

[57] **ABSTRACT**

The invention provides a method and an apparatus for coating a moving web by passing the latter through a narrow die opening while maintaining a free flowing coating material between the die wall and the web surface being coated. The coating material wets both said die wall and the web surface. As the web passes through the die the coating material between the web surface and the die wall is sheared and a coating of same is applied to the web surface. The coated web is thereafter passed through a drying zone to effect the required degree of drying.

14 Claims, 4 Drawing Figures



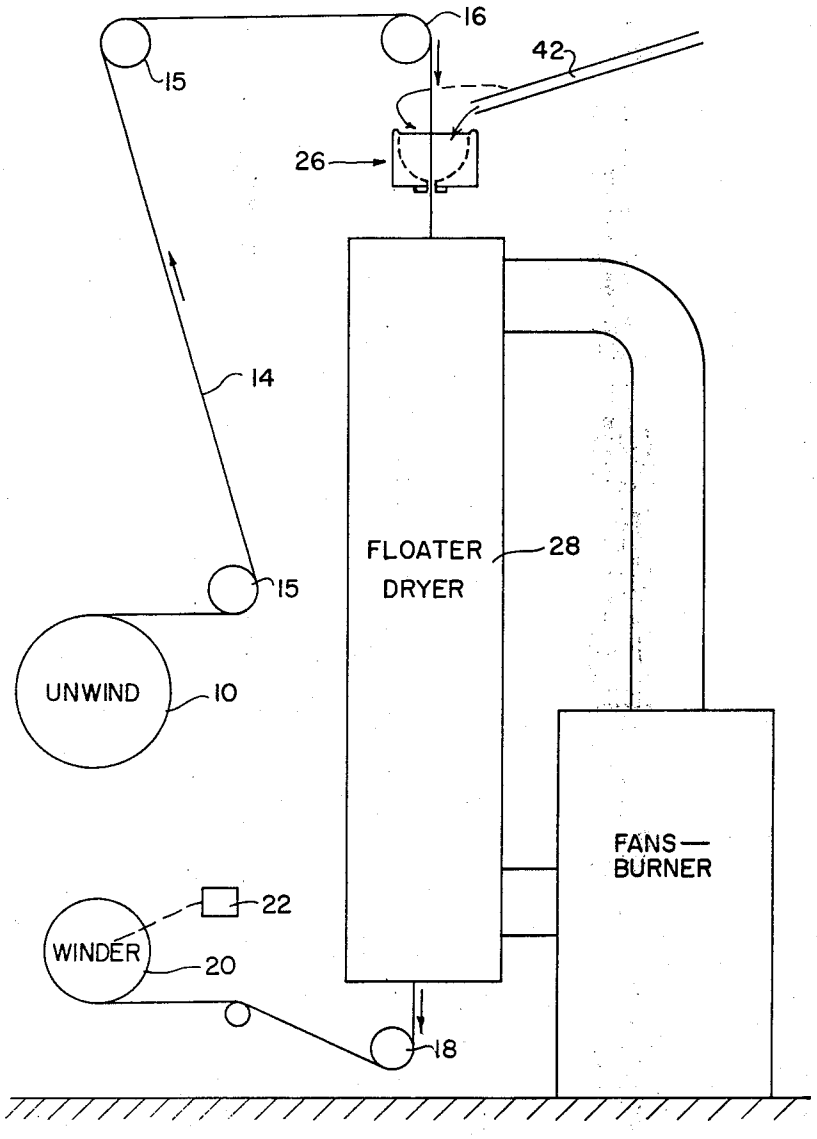

16
42
15
26
14
15
FLOATER
DRYER
28
UNWIND
10
FANS—
BURNER
22
WINDER
20
18

FIG. 1

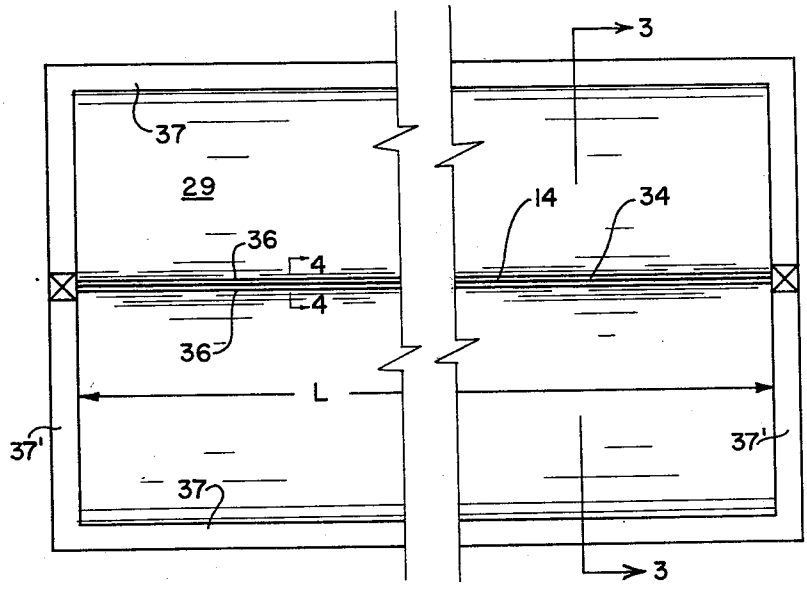


FIG. 2

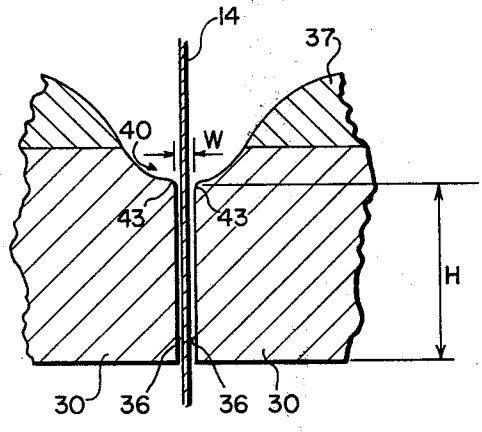


FIG. 4

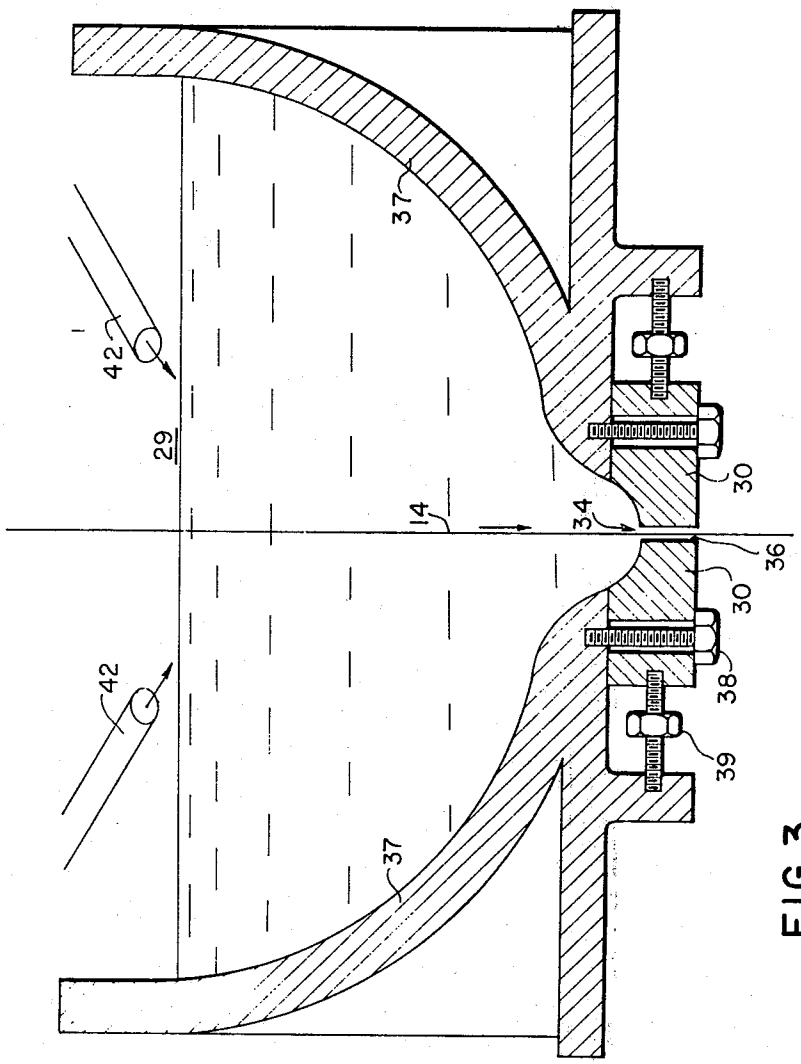


FIG. 3

APPARATUS AND METHOD FOR COATING A WEB

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of application Ser. No. 187,785, filed Oct. 8th, 1971, now abandoned This invention relates to improvements in methods and apparatus for applying a coating material to an elongated web of material.

A need has existed for quite some time for improved coating devices and methods for coating rapidly moving webs, as for example, a paper web. Known forms of coating devices generally employ some form of device which contacts the moving web, as for example, roll coaters which employ and applicator roll which rotates while in contact with the web to apply coating thereto, and blade type coaters arranged such that a pool of coating material is retained in a trough defined by the blade and the moving web. Various problems exist with these methods e.g. the coating applied may possess an undersirable pattern characteristic caused by "splitting" of the film of coating etc.; the thickness of the coating applied is difficult to control, and it is difficult to apply a pin hole free in cases where a continuous barrier film is required. Most coating devices have moving parts which tend to wear and give trouble. In addition, since high rates of shear are involved, there are limitations as to the types of coating materials which can be used. Changes in the rheological properties of the coating material at high rates of shear may cause problems.

The present invention provides ways and means for reducing to a large extent many of the problems inherent in known forms of prior art web coating devices particularly those problems ralating to coating patterns and rheological property changes. The invention provides a method and an apparatus for coating a moving web by passing the latter through a narrow coating die opening while maintaining a free flowing coating material between the a wall of the die opening and the web surface being coated. The coating material wets both said coating die wall and the web surface. As the web passes through the coating die the coating material between the web surface and the coating die wall is sheared and a coating of same is applied to the web surface. The coated web is thereafter passed through a drying zone to effect the required degree of drying.

One form of device for applying a coating material to a moving web, which bears a superficial resemblance to the present invention, is shown in U.S. Pat. No. 2,766,721 to Paquette. The device is used to apply a thixotropic slurry to a moving tape, the coated tape being used to make battery electrodes. The apparatus used to define the coating die includes spaced apart side walls one of which slopes away from the plane of the moving tape by a small angle so as to create a "wedging" action which has the effect of compressing the coating material onto the web surfaces. Provision has to be made to continuously stir the thixotropic slurry to provide uniform consistency of same.

The present invention permits the application of films of coating material which are very thin, as compared to the coating thicknesses envisaged by Paquette, to a web which may be moved at speeds many times higher than those which could be used with the paquette arrangement. The present invention does not use a wedging action to apply coating to the web; rather

the coating die is arranged and dimensioned in accordance with the thickness of the moving web to provide a high rate of shear in the free flowing coating liquid which wets both the surface and the coating die wall. It is believed that this shearing action parallel to the web surface is responsible for the substantial elimination of the undersirable coating pattern characteristics referred to above. A wide variety of coating liquids can be employed regardless of whether they be Newtonian, dilantant, thixotropic, pseudoplastic, etc. provided they wet perfectly the web surface and the orifice wall.

A specific embodiment of the invention will now be described with reference being made to the drawings wherein:

FIG. **1** is a schematic drawing of the coating device and its associated equipment;

FIG. **2** is a plan view of the coating die and coating reservoir assembly through which the web passes;

FIG. **3** is a cross-section view of the coating die and coating reservoir assembly taken along line **3—3** in FIG. **2**;

FIG. **4** is a cross-section view of a portion of the coating die, per se taken along line **4—4** in FIG. **2.**

The coating device shown in FIG. **1** includes a supply reel **10** which contains a length of the web to be coated. Reel **10** is provided with a suitable brake arrangement (not shown) to maintain a suitable tension in the web **14** from unwind to windup as slackness or flapping of the web can cause difficulties. Web **14** then passes over rolls **15** and over upper turn roll **16**; the web then passes vertically downwardly to and around lower turn roll **18.** Web **14** then passes along to a take up reel **20,** the latter preferably being provided with a take-up drive **22.** A suitable speed sensor (not shown) will be provided which will be operatively connected to the take-up drive **22** to maintain a constant speed of the running web under the possible changes in web tension brought about by variations in the braking action on roll **10** and therefore the tension of the web entering the coating unit **26** and also changes in the drag on the web passing through the coating unit **26** caused by changes in the viscosity of the liquid coating being applied, i.e. shearing forces. The speed selected is governed by the capacity of the dryer, the properties of the web, etc., and is at the discretion of the operator. It has been found and is theoretically confirmed that changes in viscosity of the coating material do not change the thickness of the film applied but do change the tension in the web at any given speed due to resulting changes in the shearing forces.

Disposed in the vertically downwardly extending run of web **14** between rolls **16** and **18** in a web coater **26** through which the web passes so that the coating material may be applied thereto. Below the web coater is a web drying zone defined by a dryer **28** which effects the desired degree of drying of the moving coated web.

With reference to FIGS. **2, 3** and **4** the web coater **26** includes reservoir **29** for coating material which leads into a coating die **34** defined by a pair of steel bars **30** disposed in side by side relation and spaced a precise distance apart so that a die opening is defined therebetween. The die opening is of generally elongated slot-like configuration and is defined by a pair of spaced, parallel planar side walls **36** defined by the sides of the spaced bars **30.** The die opening has a length dimension L slightly greater than the width of the web **14,** a relatively small width dimension W (measured normal to

the planes of the opposing side walls **36** of the coating die) and a height dimension H (measured parallel to the direction of web travel). The flat side walls **36** of the coating die are perfectly parallel to one another and they are smoothly finished. Walls **36** should be hardened sufficiently as to prevent abrasion thereof die to the shearing of certain particle containing coating materials between the opposing surfaces of web **14** and the opposing coating die walls as will be more fully explained hereinafter.

The steel bars **30** are bolted to the underside of the reservoir **29** for the coating material. Reservoir **29** is defined by a pair of opposed members **37** and end walls **37'** which together define a trough like receptacle for the coating material. As seen in FIG. **3**, each bar **30** is bolted to the underside of a respective one of the members **37** by threaded studs **38** spaced along the length of each bar. Adjustment screws **39** each having opposed left and right hand threaded portions are interconnected between each bar **30** and its associated reservoir member **37** at spaced intervals to provide for precise adjustments to be made in the width (W) of the slat-like die opening. In a typical coating machine the adjustment means should be designed to provide for adjustments from about 0.003 to about 0.030 inch with an accuracy of about ±0.00025 inches.

The bars **30** are each machined so that together they provide a hollowed out portion **40** leading from the reservoir **29** into the upper end of coating die **34.** A suitable supply means **42** supplies the coating material to the reservoir **29** to maintain a suitable level of this material therein at all times. The operating level will be somewhat above a minimum level required for operability. It appears that the optimum coating level will vary somewhat depeding on the exact coating composition and the speed of the web. The longitudinally extending edges **43** at the entrance of the upper end of the coating die opening are each provided with convex contours of relatively small but equal radius thereby to generate streamline flow in the coating liquid from the reservoir **29** into the regions intermediate the web surfaces and the coating die walls **36.** The flow patterns set up positively center the web **14** within the coating die opening providing any external forces applied to the web surface are not too great. For this reason it is important that the web run between rolls **16** and **18** be adjusted so that it passes through the geometric center of the coating die opening. It can be shown that the flow pattern into and within the die opening is such as to apply a greater force at right angles to the direction of web travel on the side having the thinner liquid layer whereby the web is self-centering. Therefore, as the web **14** passes through the die opening, equal hydraulic forces are applied to the opposing sides of the web causing it to pass through the geometrical centre of the die opening thus causing the same amount of coating material to be applied to each side of the web. At the web speeds contemplated, the hydraulic forces encountered are relatively large.

Reservoir members **37** are shown as being relatively massive in structure as they serve to support elongated bars **30** and prevent sagging thereof in the middle. This is particularly important in large machines where the length of the bars **30** may exceed 150 inches. In like manner, the support structure for the whole coating die assembly should be strong and rigid to prevent undue vibration of the whole assembly. The support structure may be designed such that one reservoir member **37** and its associated bar **30** is movable away from the other to facilitate threading up of the coating machine. After web **14** has been passed through between the two assemblies, the movable reservoir member and bar assembly will be brought forward and securely clamped or bolted to the reservoir member and bar assembly in such a way that the pre-set die opening width setting is left unchanged. Shims of the required thickness may be place at both ends of the die opening to obtain the desired spacing between faces **36.**

The speed movement of web **14** can be varied considerably. A typical web speed would be around 1500 feet per minute; at present, the web speeds contemplated range from about 10 feet per minute to about 3000 feet per minute. In like manner the average rate of shear of the coating material may be varied considerably. (The rate of shear equals web velocity divided by the distance from the surface of the centered web to the coating die wall next adjacent thereto.) A typical rate of shear is about 300,000 reciprocal seconds (sec^{-1}). However, satisfactory operation of the apparatus can be expected at shear rates anywhere from about 1000 sec^{-1} to about 600,000 sec^{-1}. There is no apparent limit to the width of the webs which can be coated and web widths of 100, 150, 200 inches etc. are visualized

The thickness of the coatings applied can be varied considerably. The preferred thickness vary from about 0.00025 to about 0.003 inches in their dried state. The 0.00025 inch thick coatings can, for example, be laid down from about a 10% solids content coating solution; in this case the wet film thickness would be 10 × 0.00025 or about 0.0025 inches thick. Pigmented films are generally laid down from solutions with suspended solids and/or in liquid emulsions with suspended solids that are about 40% water so that a dry pigmented film 0.0015 inch thick will result from a wet film thickness of about 0.0025 inches. The width W of the die opening must be very accurately chosen if the desired film thicknesses are to achieved since the film thickness will equal the distance between the surface of the centered web and the coating die wall. In the embodiment shown, the adjustment means **39** is used to achieve the desired die opening with. Once this has been set no further adjustment is required provided the solids content etc. of the coating solution is kept at a constant value.

In general, the maximum die opening with dimension (W) will be equal to twice the wet film thickness plus the web thickness. For practical purpose (W) will range from about 0.003 inch to about 0.020 inch. The 0.003 inch dimension could be used in a typical coating operation for preparing light packaging foils wherein the web is about 0.001 inch with spacings of 0.001 being maintained between each of the web surfaces and the coating die adjacent thereto. The 0.020 dimension could be used when coating a heavy paperboard about 0.14 inches thick with a heavy coating having a wet film thickness of about 0.003 inches. The required dimension (W) is thus $0.014 + (2 \times 0.003) = 0.020$ inch. For ordinary printing papers the wet film thickness may also be about 0.003 inches thus requiring a die opening width of about 2×0.003 + (paper thickness). Since these papers commonly have thicknesses ranging from about 0.002 to about 0.005 inches, the required die opening width will usually be somewhere in the range of 0.008 to about 0.011 inches.

The viscosity of the coating materials used may also be varied considerably providing the coating always remains "free flowing" as opposed to being "paste like" and is capable of wetting the web and coating die wall surface.

It has been found that there is no need to provide separate agitating devices for the coating liquid which is in the reservoir **29.** Since the liquid wets the downwardly moving web, a rolling motion is set up within the reservoir which ensures good mixing. In fact, guards may be necessary to prevent the coating liquid from splashing out of the reservoir at high web speed rates.

The dryer **28** is, per se, of a type well known in the art and must be capable of effecting substantial drying of the coated web before it reaches the lower turn roll **18**; otherwise some of the coating may tend to come off the web and build up on roll **18** with unfortunate results. Roll **18** could be a "Levitron" roll (suppled in Canada by Devtek Limited, Toronto) which maintains as air film between the roll face and the web surface. Since physical contact of the web with the roll is avoided, the problem of the web coating adhering to the roll is avoided. Since the web is wound up after passing around turn roll **18,** it is apparent that in all cases a substantial amount of web drying will be required to avoid any sticking of the layers of wound up web together. The dryer may incorporate any suitable heating means e.g. banks of electric heating elements, gas fired heaters or high velocity hot air which impinges on the web. The required rate of heat output and the length of the dryer stage will vary according to the desired speed of web travel and the nature of the coating. Those skilled in the art will of course be readily able to make the required determinations regarding the dryer for any particular machine setup.

In operation, as the web passes downwardly through reservoir **29,** its surfaces are wetted by the coating material. As the web moves down through coating die **34** the liquid between the web surfaces and the opposing coating die walls **36** of the die opening (which are also wetted by the coating material) is sheared so that viscous drag forces are exerted on the moving web. Since the coating material wets the coating die walls there is no relative movement between said walls and the liquid layers adjacent thereto. In like manner there is no relative movement between the liquid layers adjacent the opposing surfaces of the web **14.** Hence it follows that there is relative movement between the remaining various portions or layers of liquid disposed between the coating die walls **36** and the web surfaces; this shearing of the coating material in the planar regions between the coating die walls **36** and the web surfaces parallel thereto is responsible in large measure for the excellent uniformity and continuity of the coatings which may be applied to the web surfaces. Since there is no relative movement between walls **36** and the adjacent liquid, the need for hard metal wall surfaces to prevent abrasion may be questioned. However, the answer appears to be that the abrasion is a result of the presence of solid particles in the liquid which are acted upon (dragged) by the liquid which is disposed outwardly of coating die walls **36**; the resulting movement of these solid particles probably causes them to pierce the static layers adjacent walls **36** and produce the abrasion proviously referred to.

The principles of the invention will be further understood from the following typical examples:

EXAMPLE I

Web material	paper
Web thickness	.0028 inches
Web speed	15 ft. per minute
Die opening width (W)	.008 inches
Clearance between surface of centered web and die wall	.0026 inches
Rate of shear	1155 sec^{-1}
Coating material	10% solution of polyvinyl alcohol
Viscosity of coating material	1000 cps at 20 rpm (Brookfield)

The basis weight of the paper used was 31 lb. per ream, 25 × 38 − 500, and the basis weight of the finished coated paper was 38 lb. The coat weight per side was therefore 3½ lb. per ream. The standard TAPPI test with dyed turpentine showed no pinholes and complete resistance to the test liquid.

EXAMPLE II

Web material	paper
Web thickness	.0025 inches
Web speed	10 ft. per minute
Die opening width (W)	.0067 inches
Clearance between surface of centered web and die wall	.004 inches
Rate of shear	900 sec^{-1}
Coating material	standard printing coating 54% solids
Viscosity of coating material	200 cps (Brookfield)

The basis weight of the uncoated paper was 37.4 lb. per ream 25 × 38 − 500. After coating the basis weight was 60.3 lb., so that the total coating applied was 22.9 lb. per ream or 11.4 lb. per side. The coating material was a standard printing paper coating furnish containing Kaolin and binder at 54% solids of which 18% was adhesive.

EXAMPLE III

Web material	"Mylar" (Reg. T.M.)
Web thickness	.001 inches
Web speed	1500 ft. per minute
Die opening width (W)	.003 inches
Clearance between surface of centered web and die wall	.001 inches
Rate of shear	300,000 sec^{-1}
Coating material	standard printing coating 54% solids as in Example II
Viscosity of coating material	200 cps (Brookfield viscosity)

The applied coating was smooth and uniform and was judged satisfactory in all respects.

In both Examples I and II the web speeds were limited because of inadequate dryer capacity on the experimental apparatus used. Example III illustrates that web speeds many times greater than those used in Examples I and II are possible.

Several of the advantages of the arrangement described are given below.

1. There are no moving parts in the web coater; only the web moves.

2. The coating on each surface is formed by a shearing action and so is free of all rheological patterns characteristics of other methods.

3. The wet coating thickness can be controlled by adjusting the distance between the coating die walls, and once set no further adjustment is needed provided certain physical characteristics of the coating material, particularly the solids content of the coating material, are controlled.

4. A very wide range of coating color solids can be used, as for example, the various china clay (Kaolin) adhesive mixtures used for coating printing papers, various greaseproof coatings for packaging foils such as solutions of polyvinyl alcohol or polyvinyl acetate and so on so long as the coating die walls and the web surfaces are wetted thereby to produce the required shearing action in the coating material parallel to the web surface being coated.

5. A very wide range of coating thicknesses can be applied.

6. Higher coating solids with less water or other solvent can be used so that the amount of drying is minimized.

7. Pin-holing is substantially eliminated so that continuous barrier coatings can be applied in one pass. This is particularly illustrated by Example I.

8. The web moves downward in a vertical plane so that both sides can be dried before the surface need touch rollers or other means of handling a web.

9. Very high rates of web speed are possible.

10. The apparatus can easily be operated to give constant film thicknesses even with variations in viscosity. In the present invention the film thickness is set mechanically and so as long as the solids content of the coating mixture is constant, it does not matter what the viscosity of the coating is as long as the force which must be applied to the web to draw it through the coating die does not exceed that which the web is capable of withstanding.

I claim:

1. A method of coating a flexible web comprising the following steps:

a. passing the web through reservoir means containing a liquid coating material for wetting the web surface by the coating material;

b. subsequent to step (a), passing the web through a die opening defined by spaced die walls in communication with the reservoir means for being wetted by the coating material;

c. throughout the coating operation, maintaining the die walls along their entire extent in perfect parallelism with respect to one another and with a spacing having a predetermined value ranging in magnitude from about 0.003 inch to about 0.020 inch;

d. as a part of step (b), maintaining the web at a predetermined, parallel-spaced relationship throughout substantially the entire extent of the die walls for effecting coating by shearing the coating material in contact with the web surface in a direction parallel thereto, while avoiding wedging of the coating material between the die walls and the web; and

e. subsequent to steps (b) and (d), passing the coated web through a drying zone.

2. The method according to claim **1**, further including the step of maintaining said reservoir means with the coating material immediately adjacent the entrance to said die opening thus generating flow of the coating liquid from the reservoir means into the regions intermediate the web surfaces and the walls of the coating die, which flows of material into said regions generate hydraulic forces tending to center the web between the walls of the die opening to provide for equal thicknesses of coating to be applied to both surfaces of said web.

3. The method according to claim **2** wherein said walls are planar.

4. The method according to claim **1** wherein the rate of shear of said coating material is from about 1000 to about 600,000 sec^{-1}.

5. The method according to claim **1** wherein the web comprises paper.

6. The method according to claim **2** wherein the rate of shear of said coating material is not greater than about 600,000 sec^{-1}.

7. Apparatus for coating a flexible web advanced through the apparatus, comprising:

a. reservoir means for accommodating a liquid coating material;

b. a coating die connected to said reservoir means; said coating die including

1. means defining a die opening constituted solely by a pair of die walls extending in perfect parallelism to one another and having a predetermined spacing ranging in magnitude from about 0.003 inch to about 0.020 inch; said walls being exposed to the coating material in said reservoir means;

2. means for maintaining unchanged said predetermined spacing during the coating operation;

c. drier means situated downstream of said coating die with respect to the direction of web advance for removing moisture from the coated web; and

d. guiding means for passing the web in a path of travel in succession through said reservoir means for wetting the web surface with the coating material, through said die opening and through said drier means; said guiding means causing the web to pass in a predetermined spaced relationship to said walls in parallelism thereto throughout substantially the entire extent of said walls to effect coating of said web by shearing of the coating material by said walls.

8. Apparatus as defined in claim **1**, including adjusting means for setting said predetermined spacing to a selected magnitude.

9. Apparatus according to claim **7**, said coating die being arranged relative to the guiding means for passing the web in the path of travel such that the web passes intermediate the space apart walls in parallelism thereto, said reservoir means being disposed immediately in advance of the die opening through which reservoir the web passes thus generating flow of the coating liquid from the reservoir into the regions intermediate the web surfaces and the parallel walls of the coating die which flows of material generate hydraulic forces tending to effect centering of the web being the parallel walls of the die whereby to apply equal coating thicknesses to both of the opposed web surfaces.

10. Apparatus according to claim **7**, further including means for moving the web at a speed such, and wherein the die walls are spaced from the web surface sufficiently that, a rate of shear of said coating material from about 1000 to about 600,000 sec^{-1} is produced.

11. Apparatus according to claim **7** wherein the guiding means for passing the web is arranged such that its path of travel is directed vertically downwardly.

12. Apparatus according to claim **7** wherein the die walls are made of a hard, abrasion resistant material.

13. Apparatus according to claim **7** wherein the die walls are flat or planar.

14. Apparatus according to claim **7** wherein the distance between said die walls is from about 0.008 to about 0.011 inch.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,908,044

DATED : September 23rd, 1975

INVENTOR(S) : John R. Gunning

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading of the patent, under [75] Inventor, after "Oakville" insert --Ontario--; under [30] Foreign Application Priority Data, change "Oct. 13, 1971" to --Oct. 13, 1970--

Column 1, line 6, insert a period (.) after "abandoned"; line 15, change "and" to --an--; line 24, after "free" insert --film--; line 35, change "ralating" to --relating--; line 40, after "between" delete "the"; lines 65-66, change "paquette" to Paquette--; line 67, put quotes (") around "wedging".

Column 2, line 4, before "surface" insert --web--; line 32, change "take up" to --take-up--; line 34, after "suitable" insert --web--; line 52, change "in" to --is--.

Column 3, line 6, change "die" to --due--; line 23, change "slat-like" to --slot-like--;line 35, change "depeding" to --depending--; line 37, change "of" to --to--; line 44, after "applied" insert --normal--; line 55, change "centre" to --center--.

Column 4, line 10, change "place" to --placed--; line 27, change "thickness" to --thicknesses--; line 28, change "thickness" to --thicknesses--; line 35, after "and/or" insert --liquid--; line 41, after "to" insert --be-- and after "the" insert --wet--; line 45, change "with" to --width--; line 50, change "purpose" to --purposes--; line 54, after "inch" insert --thick--; line 56, after "die" insert --wall--; line 58, change "0.14" to --0.014--.

Column 5, line 18, change "suppled" to --supplied--; line 20, change "as" to --an--; line 65, change "proviously" to --previously--.

Column 6, line 61, change "characteristics" to --characteristic--

Column 8, line 38, change "1" to --7--; line 44, change "space apart" to --spaced apart; line 50, change "being" to --between--.

Signed and Sealed this

seventeenth Day of February 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks