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PAPER-COATING MACHINE

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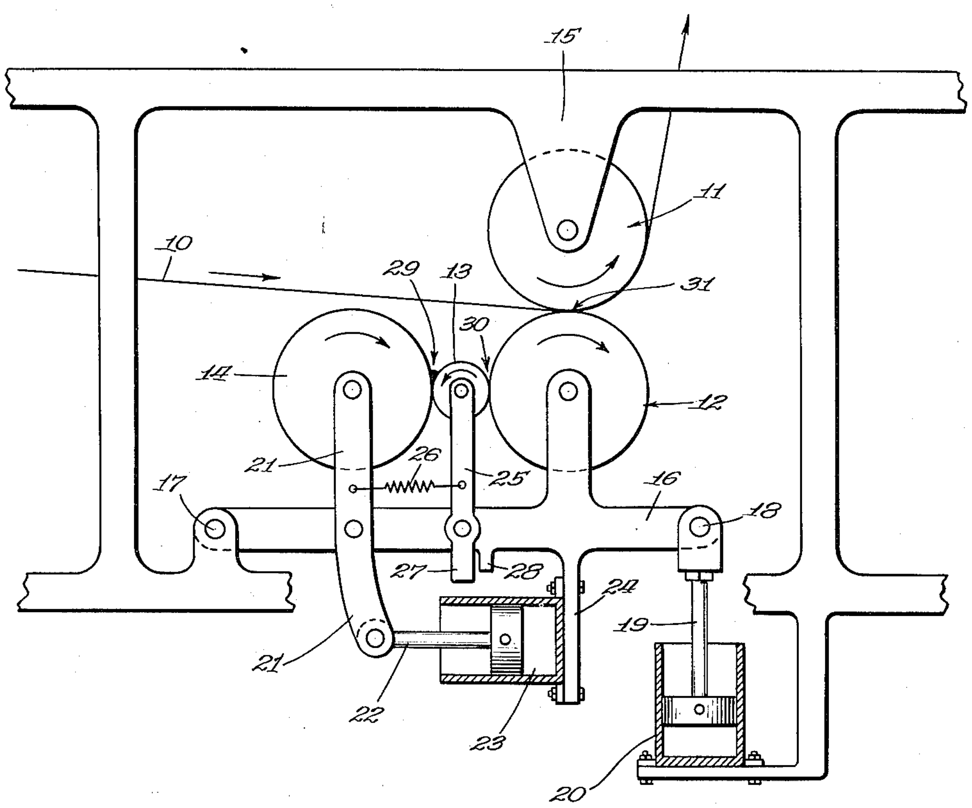

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PAPER-COATING MACHINE

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This invention relates to paper coating, and is of particular value for the coating of book papers having a desired coat weight of from two pounds to eighteen pounds per side per ream of 3300 square feet.

In recent years there has developed an increasing demand for printing papers having a mineral coating on one or both sides, depending upon the type of work to be done. The coat weight usually desired is between 3 pounds and 15 pounds per side per ream, although there is some demand for light-weight coated papers containing as low as two pounds of coating per side per ream, and also for heavy-weight papers having a coat weight as high as 18 pounds per side per ream. This demand has been stimulated by the introduction of high speed web presses equipped to use heat-set inks, and employed in the printing of magazines and other periodicals, catalogs, etc., which contain a large amount of monotone and multicolor pictorial matter.

Heretofore such papers have often been made in connection with the manufacture of paper on the paper machine, and often have been produced by a method usually described as roll-coating. One type of mechanism, which has been successfully used with that type of method, comprises a pair of pressure rolls between which the web of paper is propelled, one of said rolls receiving a supply of coating mixture which is applied to the web of paper as the latter passes through the applicator nip between the two pressure rolls.

The coating material which passes through the applicator nip is subjected to the pressure in the nip of the rolls, and when it emerges from the nip it is found that much the larger percentage of the same adheres to the paper while a relatively small percentage remains on the applicator roll. When the equipment which supplies the coating mixture to the applicator roll is functioning properly, the layer of material which adheres to the paper web after passage through the applicator nip is in such condition that the surface is relatively smooth and uniform both across the sheet and along the sheet, and is free from ripples, piles, or worm tracks. This roll coating principle is well set forth in Traquair U. S. Patent 1,518,371.

In one type of equipment used for supplying the coating mixture to the applicator roll, there are employed additional rolls which include an outer roll and a roll interposed between the outer roll and the applicator roll. The inter-

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posed roll, which may be termed a valve roll and which sometimes is described as a metering roll, is usually made of brass or other metal and may be smaller in diameter than the outer roll and the applicator roll between which it is interposed. Liquid coating mixture is supplied so as to form a pond of coating mixture in the nip between the valve roll and the outer roll, and the pressure between the outer roll and the valve roll is arranged so that there will be passed through the valve nip such amount of coating material that the web will acquire the desired weight of coat.

The nip between the intermediate metal valve roll and the applicator roll is also subject to pressure and, for the purpose of mechanical convenience in design and operation, the outer roll and the applicator roll, usually of relatively large size, receive and withstand the force which is transmitted between them by the intermediate valve roll interposed between the two large rolls. Hence, the force in the transfer nip between the valve roll and the applicator roll is usually about the same as it is between the valve roll and the outer roll.

With this type of apparatus it is not necessary, in fact I believe it is impossible, to distribute the supply of coating mixture in a smooth film on the applicator roll before the supply enters the applicator nip. However, if the pattern of roughness of the coating supply on the applicator roll is not too coarse, and if the coating supply at that point is sufficiently fluid, a smooth layer of coating mixture can be obtained on the paper.

A coating machine and method as above described have been used for several years very successfully in the commercial production of very large quantities of paper of the type described. However, it has been noticed that particularly when applying some of the heavier coatings by the use of this method and apparatus, the coated surface upon close examination, visually or otherwise, has exhibited what, for want of a better name, have been called "chatter marks" consisting of waves, ridges, or cross bars of improperly distributed coating extending across the sheet. Although these chatter marks have not interfered too greatly with the marketability of the paper, they have affected appearance of the paper and the printed result to some extent, and for that reason this cross bar or wave effect has received considerable attention from persons having to do with the operation of the method and equipment herein described.

The object of the invention is to eliminate these chatter marks or cross-bar effects, and, in general, to improve the appearance and quality of the coated paper.

I believe that this cross-bar effect may be due to some kind of hunting or pulsating action in the nip which follows the valve nip, but I have not been able either to verify or disprove this theory. As the result of a protracted series of observations and experiments (perhaps all empirical), I have discovered that these chatter marks can be practically eliminated by making a change in the relationship between the valve effect of the first two nips in the series of rolls of a roll-coating machine of the type described. According to my discovery, the valve or throttling capability of the primary valve nip should be at least as drastic as, i. e. the maximum flow capacity should be not greater than, that of the adjacent nip immediately following, i. e. the first transfer nip. By this I mean that the first transfer nip should be readily able to accept all of the coating delivered to it from the primary valve nip.

The flow of a given coating mixture which is throttled or valved through a roll nip, is in inverse proportion to the nip resistance and in proportion to the nip admittance or acceptance. An important factor of said resistance is the amount of maximum pressure per unit area in the nip and that in turn is determined by:

1. The force applied to the rolls,
2. The diameter of the rolls,
3. The materials of which the surfaces or covers of the rolls are composed.

The acceptance of the nip can be reduced by reducing the diameter of the rolls and also by using a harder cover, and by applying a higher force. The force applied to a roll nip may be expressed in terms of pounds per linear inch. However, the average pressure and also the maximum pressure per square inch in the nip may be greater or less than the number of pounds of force applied per linear inch of nip. Obviously, the greater the width of the zone of contact between the two rolls, the less is the average pressure per square inch in relation to the linear inch force applied. The width of the contact zone obviously is greater in the case of large diameter rolls than for smaller diameter rolls, and is also greater for soft rolls than for hard-surfaced rolls.

The width of the nip contact zone can usually be measured with a fair degree of accuracy, and this will enable the average nip pressure per square inch to be readily computed. The maximum nip pressure per square inch for nips of the type here involved is about 1.3 times the average pressure per square inch.

Thus, it will be recognized that the maximum per square inch pressure in the center of the nip is governed by a combination of the three factors mentioned, i. e. the force applied per linear inch, the diameter of the rolls and the hardness of the roll covers. Consequently, the maximum flow rate of material which can be valved through the nip between a pair of rolls appears to be controlled by the maximum per square inch nip pressure between the rolls, other conditions remaining constant.

Heretofore the maximum pressure per square inch in the primary or valve nip has been usually considerably less, and often much less, than the maximum pressure per square inch in the seconary or transfer nip and, other conditions being equal, the acceptance of the primary nip has been greater than that of the secondary or adjacent nip. So far as I am aware, no one has heretofore appreciated the significance of this acceptance ratio in regard to its effect upon the character of the finished coating.

The drawing is an elevation of a four-roll coating mechanism used in carrying out my invention.

The drawing shows a coating mechanism such as may be employed in an "on-the-paper-machine" coating operation. In said drawing, **10** represents the paper web as it comes from the main section of the driers of the paper machine. The sheet as so delivered need not be completely dried, although it is preferred to have less than about 10% of water in the sheet when it enters the coating press.

The main elements of the coating press, which is shown as a "one-side-at-a-time" coater, in this instance comprises a set of four rolls, viz. a top roll **11**, a main bottom roll **12** which is the applicator roll, a valve roll **13**, and an outer roll **14**. In view of the fact that the coating mechanism is designed to operate upon the full width of the sheet which may be anything up to 200 inches or more, the rolls **11**, **12** and **14** must necessarily be of large diameter and, in addition, one or more of the rolls may be provided with a suitable crown so that when the pressures of the various rolls have been properly adjusted, the pressure in each nip is uniform across the entire width of the sheet.

All of the rolls **11**, **12**, **13** and **14** are preferably driven. The rolls **11** and **12** are customarily driven at a linear speed approximating that of the paper web or machine speed, whereas the linear speed of the rolls **13** and **14** may be varied within wider limits.

The roll **11**, in the case of a single-side coater such as here illustrated, has a shell of brass or other suitable metal, whereas the outer roll **14** and the applicator roll **12** are each provided with a rubber cover. The roll **11** is mounted on a fixed support **15**, and the lower main roll **12** is mounted to rotate in bearings carried by a pair of lifter arms **16**, one end of each of which arms is pivoted on a fixed frame pivot **17**, and the other end is connected by means of a pin **18** to the piston rod **19** of a hydraulic cylinder **20**. By admitting into the cylinder **20** a supply of suitable fluid under pressure, the rocker lever **16** may be raised so as to bring the surface of the applicator roll **12** into contact with the surface of the fixed roll **11**, and apply the desired force to the applicator nip.

The roll **14** is mounted to rotate upon the upper end of a lever arm **21**. At an intermediate point on the length of said lever **21** it is pivotally connected to an intermediate point in the length of the lifter arm **16**. The lower end of the lever **21** is pivotally connected to the piston rod **22** of a hydraulic cylinder **23** carried by a bracket **24** extending down from the lower side of the lifter arm **16**.

The valve roll **13** is interposed between rolls **14** and **12** and at each of its ends is rotatably mounted upon the upper end of arm **25**, the lower end of which is also pivotally mounted upon the lifter arm **16**. The valve roll **13** in effect floats between rolls **14** and **12**. A small tension spring **26** connected between the arms **21** and **25** serves to exert only sufficient pull so that when the roll **14** is backed off to permit cleaning or for any other purpose, the roll 13 will be pulled out of contact with the roll 12. However, when the roll 14 is swung still further away from roll 12, the lower end 27 of the lever 25 engages a stop 28 on the arm 16 with the result that the roll 14 then moves away from roll 13. When in operation, the axes of the rolls 12, 13 and 14 are all in substantially the same plane as that substantially all of the force applied to the outermost roll 14 is transmitted through the first nip to all of the nips in said plane.

So for the description applies to a type of equipment which has been in successful use for a number of years. In operating said equipment an excess of liquid coating mixture is fed into the inlet of the valve nip 29 so as to form a pond of liquid coating mixture in said nip. As the rolls 13 and 14 are rotated, a limited amount of material is valved or throttled through said nip, and at the nip exit part of it is carried back into the pond on the surface of the roll 14 and another part of it is carried forward by the valve roll 13 into the under side throat of the transfer nip 30. The material which goes upwardly through the transfer nip 30 is also divided, part of the same goes into the pond on the surface of the roll 13 and the other part is carried by the applicator roll into the applicator nip 31. The part carried into the applicator nip by the applicator roll being quite fluid and mobile is not smooth, but always displays a pattern of roughness. However, in order to get a good "coat-lay," it should be well distributed all over the roll. Under proper operating conditions, most of the material which goes through the applicator nip 31 remains on the paper in the form of a smooth all-over immobile film while a relatively small percentage of the same is recycled into the transfer nip.

Heretofore no particular attention has been given to the relative hardness of the rubber covers on the rolls 12 and 14. In fact, it has been the usual practice, so far as I am advised, to equip roll 14 with a rubber covering which is substantially softer than the rubber cover of the applicator roll 12.

With the above-described equipment, where the force applied to the valve nip and to the transfer nip is practically the same, the advantages of my invention under the usual operating conditions may be obtained by equipping the roll 12 with a cover which is not appreciably harder than the cover on roll 14, so that the maximum per square inch pressure in the transfer nip 30 is not appreciably greater than the maximum per square inch pressure in the valve nip 29. The benefit accruing from the use of my invention may also be obtained by employing a larger force in the valve nip than in the transfer nip, but in large machines where the sheet width is very great this expedient is not so desirable for the following mechanical reasons.

If the mechanical force applied to the primary valve or throttling nip be very large as compared with the force which is applied to the subsequent transfer or secondary nip, it is obviously necessary to provide some independent support for the ends of the intermediate or valve roll, and that valve roll also must be made large enough or designed for a suitable crown so as to equalize the force or pressure across the sheet. This again may present a problem in connection with obtaining a uniform force or pressure in the secondary nip across the width of the sheet. There is also a further problem involved in maintaining a uniform force or pressure across the sheet in the applicator nip. Therefore, from the standpoint of the simplification of the crowning problem, particularly where it may be necessary to adjust or change the mechanical forces applied to the respective nips, the crowning problem of the various rolls becomes very serious aside from other operating difficulties due to the large forces involved. A good deal of this difficulty is avoided by the use of a valve roll which floats between the rolls on either side of it, i. e. the valve roll is not independently supported, and by the use of a valve roll which has a diameter considerably less than the diameter of the inner and outer rolls, which inner and outer rolls necessarily are required to be of large dimensions on account of deflection problems.

The use of a floating valve roll has obvious mechanical advantages as compared with a valve roll which is independently supported. Furthermore, due to the fact that the valve roll merely serves to transmit the force through the nips, it need not have as large a diameter as the inner and outer rolls. This reduces the area of the contact zone in the nip, and correspondingly increases the maximum nip pressure per square inch so that the throttling ability of the nip is increased, and conversely its acceptance is reduced. Hence, the use of a smaller valve roll enables the force applied to the valve nip to be reduced, and mechanical problems are thus greatly simplified.

In an actual case, the machine had a 133½ inch width of web, and the sheet as it entered the coating equipment had a moisture content of between 5% and 8%. The machine speed was about 900 feet per minute. The top roll was made of brass about 30-inches in diameter, and the lower or applicator roll was of about the same diameter. The outer roll was about 22-inches in diameter, and the intermediate valve roll was a straight cylindrical metal roll about 10-inches in diameter. The pressure in the applicator nip was approximately 250 pounds per linear inch. The coat weight, when using a clay-carbonate-starch coating mixture of about 60% solids content, was 10 pounds per side on a base sheet having an uncoated weight of 40 pounds per ream. The force in the supply nips was 171 pounds per linear inch. When using an outer roll having a plastometer (Pusey & Jones ⅛-inch ball) of 60, maximum pressure in the outer or primary nip was 170 pounds per square inch, and when using an applicator roll having a plastometer of 36, maximum pressure in the secondary nip was 240 pounds per square inch, so that the ratio between the maximum square inch pressure of the valve nip to the maximum square inch pressure of the transfer nip was represented by the figure

$$\frac{170}{240}$$

i. e. about .71. With this arrangement, the chatter marks were quite pronounced.

On the other hand, with the same machine, under the same operating conditions and the same force of 171 pounds per linear inch, except that there was substituted an outer roll having its hardness raised from plastometer 60 to plastometer 37, maximum valve nip pressure was 240 pounds per square inch, and when the applicator roll had its hardness reduced from plastometer 36 to plastometer 75, maximum transfer nip pressure was 137 pounds per square inch, so that the pressure ratio was changed to

$$\frac{240}{137}$$

i. e. about 1.75 as compared with .71 for the prior practice. In this case, after the solids content of the mixture had been increased to about 63% in order to compensate for the more drastic throttling due to the harder outside roll, so as to give the same coat weight of 10 pounds per side, and with all other conditions the same, the appearance of the coat lay was vastly improved. There were no chatter marks, waves, or cross bars extending across the sheet, and the coat lay was excellent.

I claim:

1. A machine for obtaining, on a paper web, an all-over, smooth, evenly distributed layer of an aqueous vehicle coating mixture containing solid materials comprising essentially a mineral pigment and an adhesive, which is provided with an application nip between which the web of paper is propelled, and with means for feeding to said application nip a limited supply of said coating mixture, which feeding means includes an outer roll, an inner roll, and a floating valve roll engaging said outer roll to form with it a primary valve nip and engaging said inner roll to form with the latter a secondary transfer nip, the axes of all of said rolls being located so that substantially all of the force applied by the outer roll to the primary nip will be transmitted through said floating roll to the secondary nip, and means for applying force to said outer roll, said primary nip serving to receive a pond of liquid coating mixture, the diameters of said outer roll, valve roll, and inner roll, and the hardness of the materials of which they are constructed being such that the maximum nip pressure per square inch in the primary nip is at least as great as the maximum nip pressure per square inch in the secondary nip so that the throttling capability of the primary nip is at least as great as that of the secondary nip.

2. A machine for obtaining, on a paper web, an all-over, smooth, evenly distributed layer of an aqueous-vehicle coating containing solid materials comprising essentially a mineral pigment and an adhesive, which comprises a pair of pressure rolls between which the web of paper is propelled, one of said rolls being a coating applicator roll and serving to receive a limited supply of coating mixture and to convey all of said supply through the applicator nip between said rolls, an outer roll and a valve roll floating between said outer and applicator rolls and engaging said outer roll and said applicator roll to form a valve nip with the outer roll and a transfer nip with the applicator roll, so that substantially all of the force applied to the other roll is transmitted to the applicator roll, said valve nip serving to receive a pond of liquid coating mixture, and means being provided for subjecting the valve nip to such amount of pressure as will valve through said valve nip an amount of coating mixture sufficient for the operation, the diameters and the hardnesses of the surfaces of the outer roll and the applicator roll being such that the maximum pressure per square inch in the valve nip is at least as great as the maximum per square inch pressure in the transfer nip.

3. A machine for obtaining, on a paper web, an all-over, smooth, evenly distributed layer of an aqueous-vehicle coating containing solid materials comprising essentially a mineral pigment and an adhesive, which comprises a pair of pressure rolls between which the web of paper is propelled, one of said rolls being a coating applicator roll and serving to receive a limited supply of coating mixture and to convey all of said supply through the applicator nip between said rolls, a rubber-covered outer roll and a metal valve roll floating between said outer and applicator rolls and movable by said outer roll into engagement with said applicator roll to form a valve nip with the outer roll and a transfer nip with the applicator roll, so that substantially all of the force applied to the outer roll is transmitted to the applicator roll, said valve nip serving to receive a pond of liquid coating mixture, and means being provided for subjecting the valve nip to such amount of force as will valve through said valve nip an amout of coating mixture sufficient for the operation, the hardness of the covering and the diameter of the applicator roll and of the outer roll being such that the maximum pressure per square inch in the valve nip is at least as great as the maximum per square inch pressure in the transfer nip.

4. A machine for obtaining, on a paper web, an all-over, smooth, evenly distributed layer of an aqueous-vehicle coating containing solid materials comprising essentially a mineral pigment and an adhesive, which comprises a pair of pressure rolls between which the web of paper is propelled, one of said rolls being a rubber covered applicator roll and serving to receive a limited supply of coating mixture and to convey all of said supply through the applicator nip between said rolls, a rubber-covered outer roll of approximately the same diameter as the applicator roll and a metal valve roll of materially less diameter than said outer roll floating between said outer and applicator rolls and movable by said outer roll into engagement with said applicator roll to form a valve nip with the outer roll and a transfer nip with the applicator roll, said valve nip serving to receive a pond of liquid coating mixture, and means being provided for forcing said outer roll towards said applicator roll so as to subject the valve nip to such amount of pressure as will valve through said valve nip an amount of coating mixture sufficient for the operation, the axes of said outer, valve and applicator rolls being arranged in substantially the same plane so that substantially all of the force applied to said outer roll will be transmitted to said applicator roll, the surface of the cover of the outer roll being at least as hard as the surface of the cover of the applicator roll.

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