

- [54] **FINISHING ROLL FOR EXTRUDED PLASTIC SHEET**
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[51] Int. Cl. **B29c 3/00, B29d 7/14**
[58] Field of Search **29/132, 130, 328, 29/337; 425/363, 362, 224, 327; 264/175, 280, 284**

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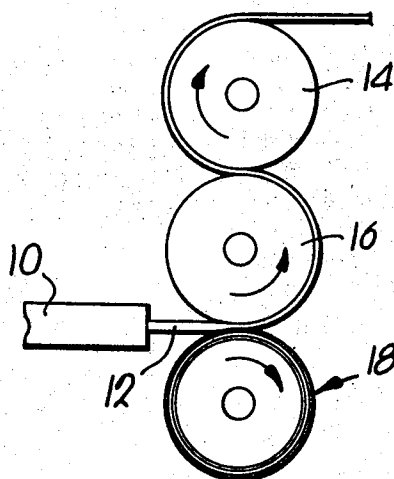
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[57] **ABSTRACT**

A molten sheet finishing roll has a rigid, metal inner core, a layer of resilient material about the periphery of the core, and a relatively thin, hard, machinable, yet flexible, metal shell encasing the resilient layer which permits the roll to compensate for deviations from uniform thickness of the sheet material such that continuous contact is maintained between the surface of the sheet material and the outer surface of the shell, resulting in a uniform finish being impressed into the sheet material.

12 Claims, 6 Drawing Figures



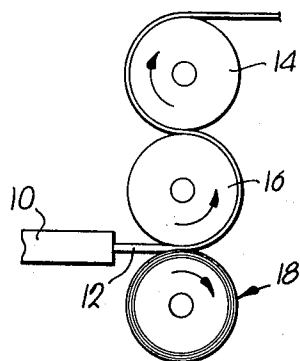


Fig. 1.

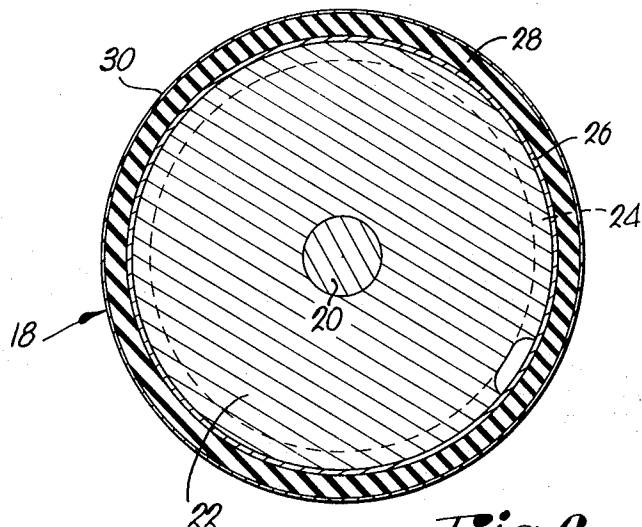


Fig. 2.

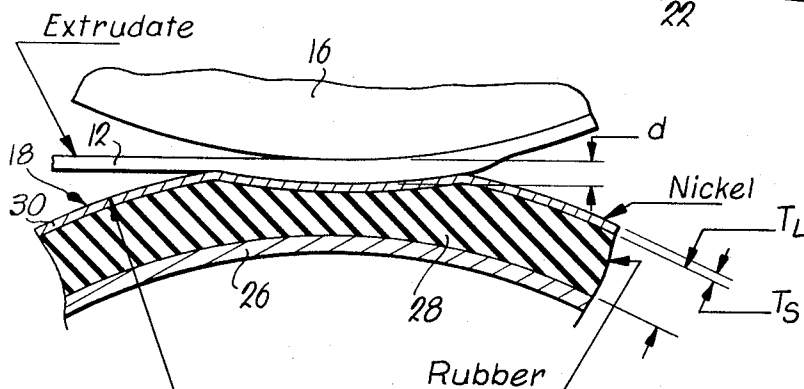


Fig. 3.

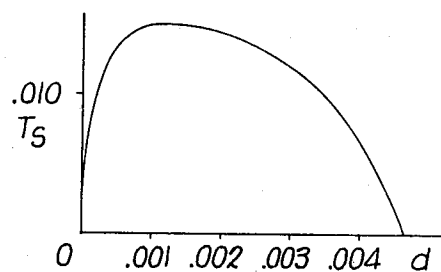


Fig. 4.



Fig. 5.



Fig. 6.

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FINISHING ROLL FOR EXTRUDED PLASTIC SHEET

This invention relates generally to equipment for producing plastic sheet material frequently used by the greeting card industry and, more particularly, to an improved finishing roll which operates in conjunction with at least one other roll to impress selected finishes into the opposed surfaces of molten plastic material issuing from an extruder.

Before the molten plastic extrudate issuing from the extruding die is allowed to cool and form clear sheet material which may be utilized for product packaging or greeting cards, the extrudate must normally pass between at least a pair of rolls which impart the selected finish to the sheet. The resulting finish may be smooth and polished, a matte surface for facilitating printing thereon, or a lenticular surface used in cards having a design with a three-dimensional effect. Where the latter use is to be made of the sheet material, one surface of the extrudate receives the lenticular finish, while the opposite surface receives a matte finish upon which the design is printed.

A problem commonly experienced by the industry is the difficulty in obtaining an extrudate having uniform thickness across the width thereof with surfaces which are free from abrupt rises and falls. In the past the practice has been to "iron out" such irregularities by shifting excess material into those other areas lacking in material, thereby arriving at uniform thickness. With relatively thick material this practice is satisfactory, since substantial molten material is available within the center of the cross-section of the sheet between the chilled, outer surface portions thereof. However, it has not proven to be entirely satisfactory where very thin material is involved, such as on the order of 0.0075 inches thick, because there is a very limited amount of molten material available between the chilled surfaces to flow from high to low areas.

As a result of the irregularities and nonuniformity of thickness, the finish is not properly imparted to the extrudate. For example, where a solid steel roll is used, thickness variations cause the roll to skip over low areas in the extrudate, leaving unfinished blotches and creases in the material. The unfinished areas are easily discerned because of differences which result in light diffraction and diffusion, thereby producing a sheet of lower overall quality and appeal. So long as the uneven portions received an even finish along with the remainder of the sheet, the discrepancies would not be visually detectable, nor would they effect the utility of the product, especially where the sheets are used for product packaging and the like.

Solid metal rolls also present problems where a lenticular finish is being impressed, instead of simply a polished finish. Because of the tendency of such rolls to "iron out" thickness deviations, the lenses of the lenticular finish may become distorted to such an extent that the three-dimensional effect of the final design is impaired.

Previously, attempts have been made to solve these problems through the use of solid rubber rolls which deflect when thickness deviations are encountered, thereby applying uniform finish to the extrudate. However, rubber rolls also have certain drawbacks, such as their inability to produce fine texture matte finished in the extrudate, the inherently poor wearing qualities of rubber, and the tendency of the extrudate to adhere to

the surface of the rubber during finishing. This is especially significant where the lenticular finish is being imparted by a solid metal roll with the rubber roll in a back-up capacity, since it is important that firm contact be maintained at all times between the extrudate and the lenticle-forming roll.

Accordingly, it is an important object of the present invention to provide a finishing roll which incorporates the ability of a rubber roll to compensate for thickness deviations in the molten extrudate as it passes between the finishing rolls, yet which retains the favorable qualities of a metal roll, enabling the new roll to produce a uniform polished surface or fine texture matte finish without rapid wearing of the roll. Basically, this is accomplished by providing a solid metal core for the roll, preferably ducted for the circulation of coolant, bonding a layer of a suitable elastomer to the periphery of the core, and encasing the resilient layer in a thin, hard metal shell to present a machinable outer surface for the roll. The thinness of the metal shell enables the latter to flex in unison with the resilient layer therebeneath when thickness deviations are encountered, while the hard surface of the shell imparts the desired finish to the extrudate with minimal wearing of the roll.

A further object of the instant invention is the establishment of a preferred range and set of values for design parameters relating to the construction of the finishing roll, such values presenting a roll which is consistent with the principles of the invention.

In the drawing:

FIG. 1 is a schematic view of equipment for producing extruded finished sheets utilizing a finishing roll constructed in accordance with the teachings of the present invention;

FIG. 2 is an enlarged, vertical, cross-sectional view of the finishing roll of FIG. 1;

FIG. 3 is a fragmentary, elevational view of the finishing equipment enlarged still further, illustrating the deflection of the novel roll when thickness deviations of the extrudate are encountered, the resilient layer and outer shell of the roll being shown in cross-section for purposes of clarity;

FIG. 4 is a plot of roll deflection as a function of shell thickness for a constant set of preferred design parameters; and

FIG. 5 and 6 are enlarged, fragmentary, vertical, cross-sectional views taken transversely of the extrudate illustrating two forms of deviations from uniform thickness often found in the extrudate.

The equipment in FIG. 1 includes an extruding die 10 from which the extrudate 12 is continuously drawn by the vertical stack of rolls 14, 16 and 18, the lowermost roll 18 being utilized as a backup finishing roll constructed in accordance with the present invention, the roll 16 preferably being a solid metal roll for imparting either a polished or lenticular finish to one surface of extrudate 12, and the uppermost roll 14 preferably being a cooling roll. Roll 18 has a central shaft 20 surrounded by a solid metal core 22 having a helical, longitudinally extending, coolant-receiving duct 24 in its outer surface which is enclosed by a thin-walled cylinder 26, a layer 28 of resilient material such as rubber, completely encompassing the outer periphery of cylinder 26 and bonded thereto, and a relatively thin, hard shell 30 of metal such as nickel encasing the rubber layer 28 for flexure therewith. It has been found that shell 30 is most easily produced by an electro-forming

process. When deviations in uniform thickness of extrudate 12, such as those in FIGS. 5 and 6, are encountered by the roll 18 during operation, instead of tending to "iron out" the deviations or skip over low spots adjacent higher peaks, the shell 30 and rubber layer 28 deflect as a unit at the points of deviation as shown in FIG. 3 to remain in continuous contact with extrudate 12 within the nip area of rolls 16 and 18. Therefore, rather than having unfinished areas or welts and other surface irregularities, the extrudate 12 acquires a uniform finish over its entire surface area. Manifestly, the quality and appearance of the finished sheet is greatly improved, and lenticle distortion is avoided.

It has been mathematically determined that the thickness of shell 30 may be calculated in accordance with the following equation:

$$T_s = \sqrt{\left(F - \frac{d_{LAV} E_L}{T_L b 2 \sqrt{d} R}\right) \left(\frac{3 \sqrt{d} R}{S_s b}\right)} \quad 20$$

where T_s equals the thickness of shell 30; d equals the deflection of the roll 18; F equals nip pressure in pounds per lineal inch; d_{LAV} equals the average deflection of the resilient layer 28 over the nip area; E_L equals the modulus of elasticity of the material of layer 28; T_L equals the thickness of layer 28; b equals a unit lineal length of shell 30; R equals the total radius of roll 18; and S_s equals the stress in shell 30. Reference may also be made to FIG. 3 which shows certain of the above design parameters with reference to roll 18.

In practice, the preferred values for the design parameters are as follows:

T_s equals 0.0137 inches; d equals 0.002 inches; F equals 167 pounds per lineal inch; d_{LAV} equals 0.001 inches; E_L equals 5,000 p.s.i.; T_L equals 0.20 inches; b equals 1.0 inch; R equals 6.25 inches; and S_s equals 95,000 p.s.i.

It is to be appreciated, however, that while the values above set forth represent preferred values, it has been found that the following range of values may be utilized to obtain satisfactory results:

T_s is within the range of 0.005 to 0.100 inches; d is within the range of 0.0003 to 0.004 inches; F is within the range of 5 to 500 pounds per lineal inch; E_L is within the range of 1,500 to 40,000 p.s.i.; T_L is within the range of 0.010 to 20.0 inches; R is within the range of 1.5 to 25.0 inches; and S_s is within the range of 20,000 to 120,000 p.s.i.

The plot in FIG. 4 of shell thickness versus roll deflection is determined by inserting the preferred values of the design parameters above set forth, except for T_s and d , into the equation, and then solving for T_s where d is within 0.0003 to 0.004 inches. Inasmuch as ideally the amount of shell deflection will correspond precisely to the amount of deviation from uniform thickness in extrudate 12, inserting a range of values for d into the equation corresponding to possible values in the thickness deviations in the extrudate 12 will furnish a set of values for the shell thickness which, in each case, is the proper shell thickness to use for the selected amount of deflection. From a practical standpoint, results beyond the range of 0.003 to 0.004 for d on the curve are meaningless.

By utilizing the deflectable roll 18 instead of either a solid metal or solid rubber roll, it is possible to obtain

a more uniform finish than has heretofore been possible. Because of the relative thinness of the shell 30, a roll is obtained which has substantially the same amount of resilience as a solid rubber roll, yet which eliminates the shortcomings of such rolls. The hard surface of shell 30 facilitates machining thereof for imparting a polished finish to the extrudate, while also being receptive to sandblasting to present a proper surface for fine texture matte finishes if such is desired.

Having thus described the invention, what is claimed as new and desired to be secured by Letter Patent is:

1. An improved sheet-finishing roll for impressing a finish into a surface of sheet material during relative movement between the roll and the sheet, wherein the improvement comprises:

a rigid central core for the roll;

a layer of resilient material of substantially uniform thickness about the periphery of said core, said layer being capable of providing uniformly distributed resilient support over the entire surface area thereof; and

a relatively thin structurally distinct, flexible, finish-impressing shell of machineable, hard material encasing said resilient layer and capable of deflecting in unison with the layer therebeneath to compensate for deviations from uniform thickness of the sheet to such an extent that continuous contact of the sheet with the shell over the length of the latter is maintained to impart a uniform finish to said surface of the sheet. latter is

2. The invention as claimed in claim 1, wherein the deflection of said shell is within the range of 0.0003 to 0.004 inches.

3. The invention as claimed in claim 1, wherein the thickness of said shell is within the range of 0.005 to 0.100 inches.

4. The invention as claimed in claim 1, wherein the deflection of said shell is within the range of 0.0003 to 0.004 inches and wherein the thickness of the shell is within the range of 0.005 to 0.100 inches.

5. The invention as claimed in claim 1, wherein said shell is constructed from nickel.

6. An improved sheet-finishing roll for impressing a finish into a surface of sheet material during relative movement between the roll and the sheet, wherein the improvement comprises:

a rigid central core for the roll;

a layer of resilient material of substantially uniform thickness about the periphery of said core; and

a relatively thin, flexible, finish-impressing shell of hard material encasing said resilient layer and capable of deflecting in unison with the layer therebeneath to compensate for deviations from uniform thickness of the sheet to such an extent that continuous contact of the sheet with the shell over the length of the latter is maintained to impart a uniform finish to said surface of the sheet, said shell having a thickness calculated in accordance with the equation:

$$T_s = \sqrt{\left(F - \frac{d_{LAV} E_L}{T_L b 2 \sqrt{d} R}\right) \left(\frac{3 \sqrt{d} R}{S_s b}\right)}$$

where T_s equals shell thickness within the range of 0.005 inches to 0.100 inches; d equals shell deflection

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within the range of 0.0003 to 0.004 inches; F equals nip pressure against the sheet; d_{LAV} equals the average layer material deflection over the nip area, E_L equals the modulus of elasticity of the layer material; T_L equals the layer material thickness; b equals a unit lineal length of the shell; R equals the total radius of the roll; and S_S equals the stress in the shell.

7. The invention as claimed in claim 6, wherein F is within the range of 5 to 500 pounds per lineal inch.

8. The invention as claimed in claim 6, wherein E_L is within the range of 1,5000 to 40,000 p.s.i.

9. The invention as claimed in claim 6, wherein T_L is

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within the range of 0.010 to 20.0 inches.

10. The invention as claimed in claim 6, wherein R is within the range of 1.5 to 24.0 inches.

11. The invention as claimed in claim 6, wherein S is within the range of from 20,000 to 120,000 p.s.i.

12. The invention as claimed in claim 6, wherein T_S equals 0.0137 inches; d equals 0.002 inches; F equals 167 pounds per lineal inch; d_{LAV} equals 0.001 inches; E_L equals 5,000 pounds per square inch; T_L equals 0.20 inches; b equals 1 inch; R equals 6.25 inches; and S_S equals 95,000 p.s.i.

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