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Beam et al.

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[45] **Nov. 4, 1975**

[54] **COATING CONTROL**

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[73] Assignee: **Jones & Laughlin Steel Corporation,** Pittsburgh, Pa.

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[52] **U.S. Cl.** .... **427/433;** 15/306 A; 15/418; 118/63; 239/592; 427/434; 427/436

[51] **Int. Cl.**[2] **B05D 1/18**

[58] **Field of Search** .... 117/102 M, 114 R, 114 A, 117/114 B, 114 C; 118/63; 15/306 A, 307, 308, 415, 418, 419, 420; 134/64, 122; 239/592, 593, 594, 595, 597, 589, 564, 590, 592, 594, 597; 117/102 R

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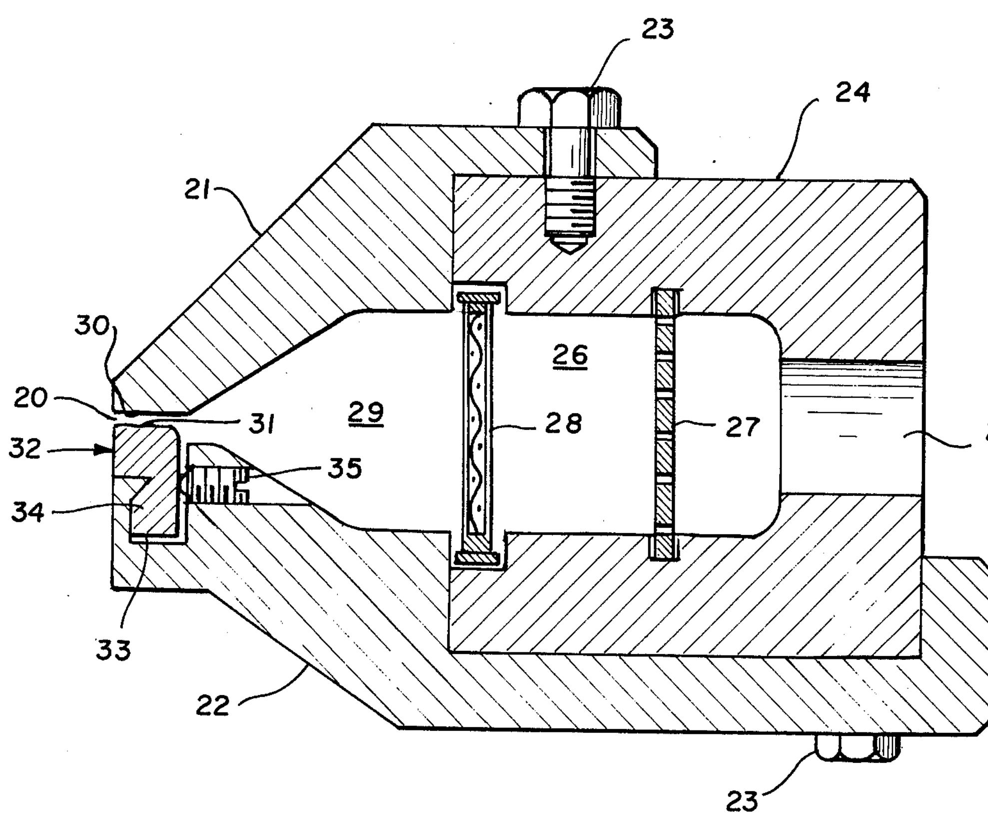
[57] **ABSTRACT**

The weight and distribution of a coating applied to a moving substrate are controlled by directing a gaseous fluid through a nozzle opening to the substrate while the coating is in a liquid state. The gaseous fluid impinges onto the substrate and removes excess coating material and generally smooths out the liquid coating. The nozzle opening tapers uniformly from its ends to about its midpoint causing the gaseous fluid passing therethrough to establish a coating profile which is substantially uniform or which is slightly heavier along the central portion of the substrate than along the edges. In accomplishing coating control, the rate of taper on the profile of the nozzle opening is adjusted in response to changes in coating operation variables which affect coating weight and distribution. The apparatus of the invention allows for rapid changes to be made in the profile of the nozzle opening.

4 Claims, 4 Drawing Figures



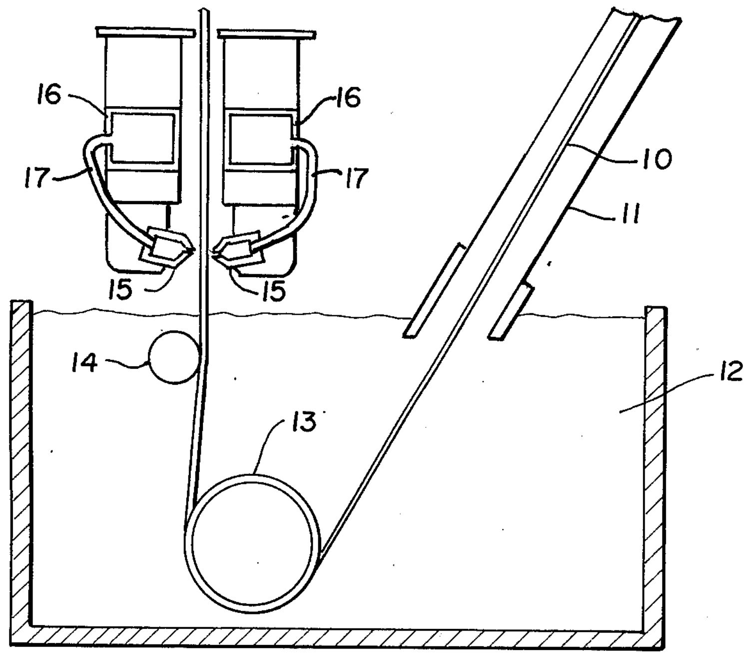

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Fig. 1.

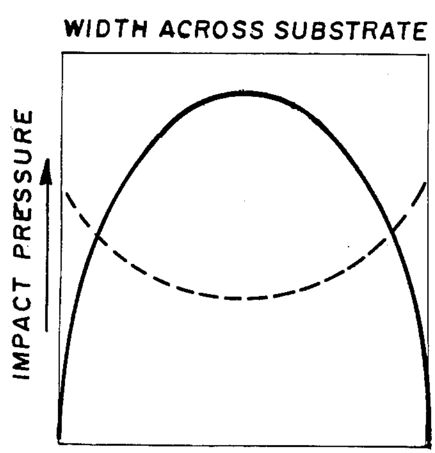
WIDTH ACROSS SUBSTRATE
IMPACT PRESSURE

Fig. 2.

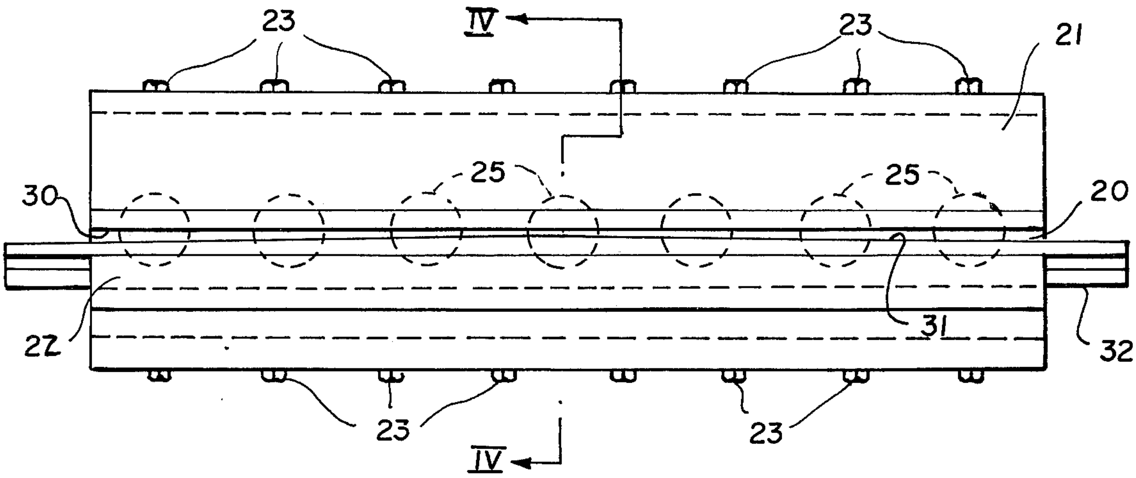

Fig. 3.

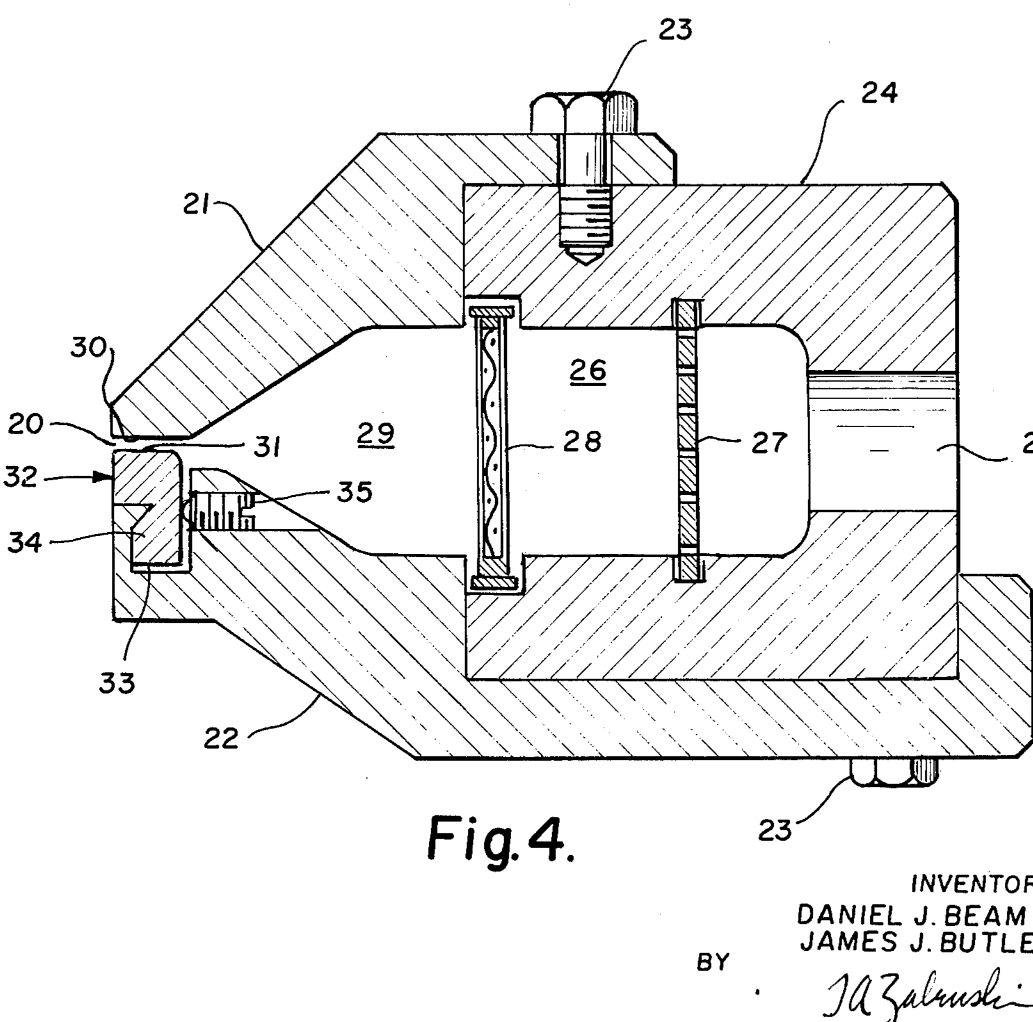

Fig. 4.

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COATING CONTROL

This invention relates generally to method and apparatus for controlling the coating of a substrate, and, more particularly, to the use of fluid wiping means for controlling the weight and distribution of a coating applied to a moving substrate. The invention has special utility in hot-dip coating operations, such as the hot-dip galvanizing of steel strip.

It has been common practice to employ coating rolls to control the thickness of a coating applied in a liquid state to a substrate. For example, in the production of hot-dip galvanized steel sheet, driven exit rolls which are about half-submerged in the zinc coating pot are used to control the thickness of the coating applied to the steel strip passing therebetween by adjusting both the pressure between the rolls and the relative position of the rolls with respect to the surface of the molten zinc bath. The use of coating rolls to control coating thickness is not completely satisfactory, however, and other techniques have been adopted. One such technique is that of fluid wiping. In a fluid wiping process a gaseous fluid such as steam, air, or other gaseous medium is passed through a narrow slot-type opening in a nozzle and directed against the substrate being coated while the coating material is still liquid to remove excess coating material and to generally smooth out the liquid coating. Such nozzles are referred to as fluid knives or, where air is used as the wiping fluid, air knives.

While fluid wiping techniques have overcome many of the disadvantages associated with the use of coating rolls, there has been a need to improve the performance of such techniques. For example, it has been our experience that for conventional line speeds, the use of an air knife having a planar, rectangular-shaped opening to control the coating thickness in a hot-dip galvanizing process, as described in British Pat. Specification No. 588,281, results in (1) a non-uniform coating being formed, the central portion of the strip having a lighter coating weight than the edge portions, and (2) the formation of an associated "heavy edge" or bead of zinc coating within one-half to one-quarter inch of the strip edges. These features result in spooled coils or coils with shape problems. Preferred coating profiles are ones having a uniform coating weight across the strip or a slightly heavier coating weight at the center of the strip than along the edges. The preferred profiles result in improved strip flatness and facilitate strip coiling, particularly with respect to light gauge products.

We have found that the undesirable coating profiles associated with the use of planar, rectangular-shaped nozzle openings result because such nozzles deliver the fluid wiping medium to the strip in a manner whereby higher impact pressures are established along the central portion of the strip than along the edges and consequently more coating material tends to be removed from the strip center than from the strip edges. We have also found that an impact pressure distribution or profile which decreases substantially uniformly from the ends of the substrate to the center of the substrate can be established by employing a nozzle having an opening or slot tapering substantially uniformly from its edges towards its midpoint. Such an impact pressure profile can provide either a uniform coating profile or a coating profile which is slightly heavier along its center than along its edges. The exact coating profile obtained is related generally to the rate of increase of the impact pressure from the center of the substrate to the edges, and the impact pressure profile is a function in part of the nozzle slot characteristics, i.e., the rate of taper of the slot or the slot profile. Accordingly, the present invention provides for controlling the coating profile by controlling the nozzle slot characteristics. We have also found that a tapered nozzle opening or slot of the type described eliminates the formation of heavy edges provided the taper is of substantially uniform slope.

In addition to the foregoing, we have also determined that in a continuous coating operation, such as the continuous hot-dip galvanizing of steel strip, the coating weight is a function primarily of line speed, strip width and matte, molten zinc bath temperature, nozzle to strip distance, air flow rate through the nozzle, and nozzle slot characteristics. More particularly, the coating weight can be approximated by a linear equation of the form:

$$\text{Coating Weight} = C_1 + C_2\,(\text{Air Flow Rate}) + C_3\,(\text{Nozzle to Strip Distance}) + C_4\,(\text{Line Speed}) + C_5\,(\text{Strip Width}) + C_6\,(\text{Strip Matte}) + C_7\,(\text{Bath Temperature}) + C_8\,(\text{Nozzle Slot Characteristics})$$

The terms C_1 through C_8 represent constant terms which are unique for any particular coating operation. Accordingly, the present invention not only provides for changing the rate of taper of the nozzle slot to control coating profile, but, in addition, provides for changing the rate of taper of the nozzle slot in response to variations in the other operating conditions which influence coating weight to thereby control coating weight. The invention further provides both for making such changes rapidly so as to minimize line delays and yield losses and for maintaining a desired coating profile when the strip tracks transversely of its preset path of travel.

An object of the present invention is to provide fluid wiping process and apparatus for controlling the weight and distribution of a coating applied in a liquid state to a moving substrate. Another object of the invention is to provide such control in a continuous hot-dip galvanizing operation, using air as the wiping fluid. Another object of the present invention is to provide such control employing an air knife having a tapered opening, the rate of taper of the opening being changed in response to changes in other variables affecting the coating weight and profile. Yet another object of the invention is to provide means for rapidly making changes in the taper rate of the air knife opening in order to minimize line delays and yield losses. Still another object of the invention is to provide such control while compensating for substrate tracking.

These and other objects and advantages of the invention will appear in the course of the following detailed description of a presently preferred embodiment thereof, with reference to the accompanying drawings in which:

FIG. 1 is a schematic elevation view of a section of hot-dip galvanizing line having an air wipe system for controlling the thickness of the zinc coating deposited on a steel strip in accordance with the invention.

FIG. 2 is a graphical representation of the impact pressure distribution established across a substrate subjected to an air wipe system according to the present invention and the impact pressure distribution established across a substrate subjected to an air wipe system which provides undesirable coating characteristics.

FIG. 3 is a front view of the fluid knife of the invention.

FIG. 4 is a sectional view of the fluid knife taken along lines IV—IV of FIG. 3.

The invention is particularly described herein in conjunction with the continuous hot-dip galvanizing of steel strip, but it will be understood that the invention can be applied to various coating operations wherein a coating material in liquid form is applied to a substrate. FIG. 1 schematically illustrates a section of a hot-dip galvanizing line wherein a steel strip **10,** after exiting from a conditioning furnace, not shown, passes downwardly through protective snout **11** into a molten zinc bath **12,** around pot roll **13,** and upwardly into contact with stabilizer roll **14** and past air knives or nozzles **15—15** to a cooling tower and suitable recoiling equipment, also not shown.

Air under pressure is supplied, from a source not shown, to distribution headers **16—16** and from the headers to the nozzles **15—15** through a series of flexible metal hoses **17—17** to maintain uniform flow distribution into the nozzles and through the nozzles to the strip. The air flow through the nozzles is controlled by suitable valves in the lines connecting the air source and the distribution headers. The nozzle openings or slots through which the air is directed to the strip extend at least across the width of the strip and preferably extend beyond the strip edges. The air exiting from the nozzles impinges onto the strip and removes excess molten zinc therefrom and generally smooths out the molten zinc across the strip, thereby controlling coating weight and distribution. Stabilizer roll **14** is adjustable transversely of the upward path of travel of the strip to maintain the strip substantially vertical and the entire surface of the strip at the point of impingement essentially parallel to the nozzle faces. The nozzles are also adjustable transversely of the upward path of travel of the strip to facilitate the positioning of the strip therebetween.

As mentioned above, we have found that with respect to nozzle slot configuration, at conventional line speeds, a planar, rectangular slot of the type described in aforementioned British Pat. Specification No. 588,281, results in a coating thickness profile wherein the coating is lighter along the central portion of the strip than along the edge portions. In addition, heavy edges or beads of coating material are formed adjacent the strip edges. The reason for this is that such a nozzle slot causes an impact pressure distribution to be established across the strip which varies from a maximum at the center of the strip to a minimum at the edges of the strip; and as a result more liquid coating is removed from the center of the strip than from the edges. This impact pressure distribution is shown graphically as the solid line in FIG. **2.** We have found that a uniform coating thickness across the strip or a coating thickness slightly heavier along the central portion of the strip than along the edges is provided by nozzles having openings which taper uniformly from their edges to substantially their midpoint, as shown in FIG. **3.** Such nozzle openings result in impact pressure distributions being established across the strip which vary uniformly from a minimum at the center of the strip to a maximum at the edges of the strip as shown graphically in the dotted line in FIG. **2.** Also, the area of wiping fluid impact on the substrate is greater along the edges of the substrate than along the central portion thereof. The exact impact pressure distribution established across a strip is a function in part of the nozzle slot configuration or the rate of taper of the slot and the type of impact pressure distribution established by the tapered nozzle opening of the invention results in the formation of either a uniform coating thickness or a coating thickness slightly heavier at the center of the strip than at the edges, depending on the magnitude of the difference between the maximum and minimum impact pressures. As the magnitude of this difference increases so does the magnitude of the difference between the coating thickness along the central portion of the strip and the coating thickness along the strip edges. Thus, while the coating profile does not correspond exactly to the impact pressure profile, the impact pressure distribution established across a strip controls the coating profile in a general way.

FIGS. **3** and **4** illustrate a fluid knife or nozzle embodying the teachings of the present invention, said fluid knife having a nozzle opening **20** which tapers uniformly from its ends to substantially its midpoint. The fluid knife includes an upper lip **21** and lower lip **22** suitably mounted by bolts **23—23** to nozzle body section **24.** A plurality of passageways **25—25** are provided across the rear of body section **24** and when the knife is in use flexible metal hoses **17—17** leading to distribution header **16** are connected thereat. The passageways **25—25** lead into chamber **26** of body member **24.** a baffle **27** is supported within and across chamber **26** to aid in distributing the air or other wiping fluid delivered to the chamber **26** from the distribution header. In addition, a screen **28** is supported across chamber **26** to further aid in distributing the wiping fluid. Upper lip **21** and lower lip **22** form a longitudinally extending chamber **29** through which the wiping fluid passes before exiting from the nozzle through opening **20.**

The fluid knife or nozzle slot **20** is defined by a planar surface **30** on upper lip **21** and a tapering surface **31** on insert member **32** which is slidably mounted in lower lip **22.** Surface **31** tapers uniformly toward surface **30** from the ends of insert **32** to substantially the midpoint of the insert. A longitudinally extending slot **33** is provided in lower lip **22** and a complementary keying section **34** is provided on insert **32** whereby the insert is slidably mounted in the lower lip. The insert is releasably secured to the lower lip by retaining means in the form of conventional ball spring plungers **35—35** threadably secured to said lower lip. Thus to change insert members to control coating weight and distribution, it is simply necessary to withdraw from one end of the lower lip the insert which is in place while simultaneously inserting from the other end of the lower lip an insert having a different taper at surface **31.**

In various coating processes, such as the hot-dip galvanizing process described, the strip from time to time tends to track or move laterally of its path of travel. When tracking occurs the center of the nozzle slot will not be aligned with the center of the strip, and, consequently, in applying a coating heavier at the center, the heavier coated area wanders from the center of the strip as the strip tracks. This is undesirable because it reduces the quality of the coated product and it makes the strip more difficult to coil uniformly. Accordingly, as illustrated in FIG. **3,** insert member **32** preferably extends beyond both ends of the nozzle whereby if the strip tends to track transversely of its upward path of travel, the insert may be adjusted correspondingly to maintain the midpoint of the slot substantially at the midpoint of the strip.

It will be understood that the characteristics of various coating operations and coating lines differ one from the other so that a nozzle slot taper which produces the desired coating profile under specific operating conditions in one coating operation may not produce a similar desired coating profile under the same conditions in a second coating operation. However, based on the present disclosure one skilled in the art can readily determine for a particular coating operation or coating line the relationships between nozzle slot taper and operating conditions which provide specific desired coating profiles and weights.

We claim:

1. A process for controlling the coating of a substrate comprising, depositing a coating material as a liquid on the substrate, moving the substrate in a longitudinal path past a nozzle having an elongated opening which extends at least across the width of the substrate, said nozzle having two nozzle lips and a tapered insert member releasably supported by one of the nozzle lips, one of said lips and said insert member forming said elongated opening, said opening tapering substantially uniformly from its ends to substantially its midpoint, forcing a gaseous fluid through said opening and directing the gaseous fluid to the substrate to cause said gaseous fluid to impinge onto the substrate whereby to establish a desired coating thickness profile and weight on the substrate, and in response to changes in variables affecting the coating thickness profile and weight, changing the taper of the nozzle opening by withdrawing said insert member while simultaneously inserting an insert member having a different taper to thereby control coating weight.

2. The process of claim **1** including adjusting the location of the midpoint of the nozzle opening to be substantially opposite the midpoint of the substrate as the substrate tracks laterally of its longitudinal path.

3. The process of claim **1** wherein the coating material is zinc, the substrate is steel and the gaseous fluid is air.

4. The process of claim **3** including adjusting the location of the midpoint of the nozzle opening to be substantially opposite the midpoint of the substrate as the substrate tracks laterally of its longitudinal path.

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