ABSTRACT

This specification discloses an apparatus for freezing the molten zinc coating on a moving wire after it issues from a wiping box for controlling the coating, comprising two or more water discharge passages for forming jets of water spaced along and transversely intersecting the line of movement of the wire, said jets being controlled whereby the flow of water in each jet is non-turbulent, and an air discharge duct having a narrow discharge slit for creating a flow of air directed transversely to the line of movement of the wire between said jets and the wiping box.

12 Claims, 8 Drawing Figures
PRIMARY WATER QUENCH

This invention relates to apparatus for cooling coatings on moving wires, strips, or other continuous lengths of material, hereinafter termed "wire." The invention is especially useful for freezing molten zinc or zinc alloy coatings produced by hot-dip galvanizing although not restricted thereto.

In hot-dip galvanizing, the wire to be galvanized is drawn through a bath of molten zinc or zinc alloy and emerges from the bath in a substantially vertical direction. Commonly, the wire then passes immediately through a wiping bed whose function is to control the smoothness and thickness of the coating. Our British Pat. No. 1,256,928 describes an improved wiping technique which permits considerably higher throughput speeds in hot-dip galvanizing operations. Briefly, in this technique, the wire is drawn through a bed of particles floating on the bath of molten zinc, and a non-oxidizing gas is passed continuously through the bed at a rate sufficient to exclude air, said gas containing at least a small proportion of hydrogen sulphide. The bed of particles is retained in a box having an open lower end which is immersed in the zinc bath, and an open upper end through which the wire emerges and through which the gas escapes. For convenience, this arrangement is hereinafter called the wiping box.

The higher throughput speeds made possible by this technique have reduced the time that is available for freezing the molten coating. More effective means are therefore required for the initial or primary quenching of the coating, but without however disturbing its smoothness or uniformity.

In some present galvanizing plants, the initial or primary quench for freezing the coating comprises a single jet of water, this being followed by cooling of the whole wire in an apparatus known as a secondary quench. However, when wires are being galvanized at high speeds, and especially in the case of thick wires and/or heavy coatings, more effective cooling is required. The large jets required for thick wires are prone to having a turbulent flow which disturbs the coating. In any event, a conventional single jet does not cool the coating sufficiently. This is partly attributable to inadequate contact time between wire and jet and partly to the formation of an insulating jacket of steam around the wire, which reduces the efficiency of heat transfer from the wire to the cooling water.

One object of the present invention is to provide water quenching apparatus that freezes the molten zinc coating on a wire without disturbing its smoothness and uniformity and that is effective under the conditions of throughput speed, wire thickness, and coating weight made possible in hot-dip galvanizing by the new wiping technique. However, it should be understood that the invention, while being particularly suited to galvanizing operations involving high line speeds, is equally applicable to lower line speed galvanizing and other lower or higher speed coating operations or other treatments.

In the present context, high speeds are those exceeding 1.3/d metres per second and ranging up to about 4.6/d metres per second, where d is the diameter of the wire expressed in millimetres. Heavy coatings include those designated Type B in Table 7-24 in the American Iron and Steel Institute specification entitled "Minimum ounces of zinc per square foot of uncoated wire surface, or heavier coatings." However, application of the invention is naturally not restricted to galvanizing operations involving these speeds or coating weights.

According to one aspect, the invention provides an apparatus for cooling coatings on moving wires comprising a liquid discharge passage or passages for forming a jet of cooling liquid intersecting the line of wire movement and having a height substantially greater than its width, and means for controlling the jet issuing from said passage or passages whereby the flow of liquid is non-turbulent.

A jet is considered non-turbulent when there is no significant adverse effect on the smoothness and uniformity of the coating during cooling. In practice, non-turbulent jets have a clear, glassy appearance as distinct from a cloudy, bubbly appearance when the flow is turbulent.

The term 'height' refers to the dimension of the jet measured in the direction of wire travel in the region of the intersection of the jet and the wire. The term 'width' refers to the dimension of the jet in a transverse direction to the flow of water and to the wire in the region of the intersection of the jet and the wire.

In one embodiment of this aspect, the increased height of the jet is achieved by combining the streams from two or more adjacent discharge tubes, the flow rates of the individual streams having been adjusted so that they merge into a single non-turbulent jet.

In another embodiment, the increased height is achieved by directing a non-turbulent liquid jet which is coaxial with the wire for a large part of the height of the jet, and flows in the same direction as the movement of the wire, the water at the downstream end of the jet being recovered by entrainment in a transversely directed air stream.

According to another aspect, the invention provides a coating cooling apparatus comprising two or more liquid discharge passages for forming jets of cooling liquid spaced along and transversely intersecting the line of movement of the wire, means for controlling the jets issuing from said passages whereby the flow of liquid in each jet is non-turbulent.

Where the cooling apparatus is used to quench zinc coatings on hot-dip galvanized wires the water jets are located immediately above the opening of the wiping box. In accordance with conventional practice, the bulk of the water in the jets is recovered downstream from the intersection with the wire by means of water catch troughs. However, smaller quantities of water in the form of drips and splashes are generated in the region of the intersection of wire and jets. It is therefore desirable to provide means for minimizing the entry of water into the wiping bed, at least to the extent where the wiping operation is not adversely affected. Hence, the apparatus of the invention may also include what may be described as an air curtain above the opening in the wiping box. The curtain comprises a flow of air, or other suitable gas such as nitrogen, above and across substantially the whole extent of the opening in the wiping box.

In the case of thick wires and/or at very high throughput speeds, we have found that the conventional arrangement of a jet impinging on one side only of the wire has the disadvantage of noticeably less effective cooling of the other side, and thus gives rise to undesirable non-uniformity in the coating. Hence, the apparatus of the invention may include jets which impinge on both sides of the wire. The jets may be obtained by
merging the streams from several discharge tubes, or from a single discharge tube, or by a mixture of these methods.

In practice, some transverse movement or wander of the wire inevitably occurs. Jets considerably wider than the wire thickness are therefore needed if the wire is not occasionally to wander too close to or even beyond the edge of the jet. In order to offset the natural tendency of water to form a cylindrical jet owing to surface tension, we have found it advantageous to use discharge tubes having a bore of rectangular cross-section. By orienting the major dimension of the bore transversely to the wire, jets of enhanced width are obtained. Where a still wider jet is required, we have found it best to make up the width by combining the streams from two adjacent discharge tubes.

In practice, a number of wires moving along parallel paths in the same plane are usually galvanized simultaneously. If the wires are fairly closely spaced, the jets cooling adjacent wires may be combined to form a single wide jet spanning a number of wires. The height of the wide jet may be increased by combining jets whose height in turn is made up by combining the streams from two or more discharge tubes as already explained. A wide jet spanning a number of wires can have the advantages in practice of economy in the use of water and of carrying away drips and splashes from jets situated higher up, thus helping to further reduce the entry of water into the wiping box. Hence, the apparatus of the invention may further include a non-turbulent jet of water of sufficient width to accommodate a number of parallel wires in the same plane, the width of the jet being made up by combining the streams emanating from a number of laterally adjacent discharge tubes. In this case, the term width, when used in comparison of the height of the jet as discussed above, refers to the transverse dimension of the stream or streams normally associated with one wire.

Another aspect of minimizing the entry of water into the wiping bed arises during the interruptions in wire throughput that inevitably occur in practice. Water would then run down the stationary wire into the wiping bed. To blow this water away, the invention provides for the use of air jets located above the opening in the wiping box and directed transversely at the wire whenever the latter is stationary.

Several embodiments of the invention will now be described with reference to the accompanying, somewhat schematic, drawings in which:

FIG. 1 is a side elevation of the relevant part of a wire galvanizing plant showing the position of a primary quench embodying the invention in relation to other components;

FIG. 2 is a side elevation of the primary quench apparatus of FIG. 1;

FIG. 3 is a side elevation of another embodiment of the invention in which jets impinge on both sides of the wire;

FIG. 4 is a side elevation of another embodiment of the invention incorporating three jets, each jet being made up by combining the streams from four discharge tubes;

FIG. 5 is a side elevation of another embodiment of the invention incorporating a single jet, made up by combining the streams from eight discharge tubes;

FIG. 6 is a side elevation of another embodiment of the invention incorporating a coaxial jet;

FIG. 7 is a side elevation of a preferred form of water discharge tube with a bore having a rectangular cross-section, and

FIG. 8 is a sectional view plan view of an arrangement of two tubes of the type shown in FIG. 7, taken along line 8-8 of FIG. 7.

The galvanizing plant arrangement shown in FIG. 1 includes a wiping box A of the type described in British Pat. No. 1,256,928, followed by a primary quench B embodying the invention and rollers C for guiding and steadying the wire W. Providing the cooling in the primary quench is sufficiently effective, a secondary quench need not be used immediately following the primary quench and is therefore not shown in FIG. 1.

However, a conventional tertiary quench for cooling the whole wire is required and is shown at D as being one of the cascade type.

Referring now to FIG. 2, the primary quench B comprises a vertically disposed linear array of discharge tubes 2 inclined at 45° to the vertical along the line of movement of the wire W, the tubes being spaced vertically by about 15 mm. The discharge tubes 2 are arranged in four sub-sets of two tubes, each connected to a water supply manifold 3. Each manifold 3 in turn is connected to a pipe 4 equipped with a valve or other adjustable restrictor 5 and connected to a water main 6. Depending on the water diameter, coating weight and throughput speed, the supply of water to one or more manifold 3 may be turned off. The valves 5 are adjusted in use so that the flow rate is substantially the same for all the sub-sets and so that the flow from each tube 2 is non-turbulent. As already mentioned, the water jets then have a clear, glassy appearance, as distinct from a cloudy, bubbly appearance when the flow is turbulent.

A water catch trough 7 is positioned on the opposite side of the wire W to the tubes 2 to catch the water discharged from the tubes 2. A drip tray 8, secured to the lowermost manifold 3 and equipped with an adjustable drip deflecting blade 9, is positioned under the set discharge tubes 2, the water collected in the catch trough 7 and the drip tray 8 being usually recovered for re-use, after cooling, instead of being discharged to waste.

In order to minimize the number of drips and splashes of water that fall into the opening in the top of the wiping box B in FIG. 1. both during the start-up period and during normal running, a horizontal air curtain is provided by discharging air from blower 9 (FIG. 1) through a nozzle 11 which has a narrow horizontally elongate discharge slit 12, about 1.5 to 2 mm in height. The height of the air curtain in the region of the intersection with the wire is about 8 to 15 mm. Good results have been obtained by using a centrifugal blower capable of delivering air at a pressure of 3 to 4 KilPascals at a rate of 20 to 24 litres per second per wire. The width of the nozzle and slit is made large enough to ensure that the air curtain extends over the full extent of the opening in the wiping box A, which in turn is related to the number of parallel wires that the apparatus is capable of galvanising simultaneously. It will be appreciated that in practice, several parallel wires are usually processed simultaneously and each wire has its own primary quench B.

Under production conditions, interruptions to wire movement occur periodically for various reasons and water from the tubes 2 then runs down the stationary wire W. In order to blow this water away from the opening in the wiping box A, a high velocity jet of air,
obtained from the usually available supply of compressed air at 460 to 700 kilopascals, is directed transversely from pipe 13 at the wire whenever the latter is stationary. In FIG. 1, the pipe 13, which is typically 8 mm in diameter, is shown coming from a solenoid-operated valve V which is energised automatically when the wire W is stationary. Although not shown, the end of the pipe 13 is protected from damage by wire knots or other misuse by suitable reinforcement.

Alternatively, or in conjunction with the air jet, a solenoid operated valve may be provided in the water main 6 to stop the supply of water when even the wire W is stationary.

For setting up the apparatus in order to obtain the best results, various positional adjustments are provided. The set of discharge tubes 1 is adjustable vertically up and down, horizontally towards and away from the wire, and sideways in a lateral direction to wire W. The water catch trough 7 is also adjustable horizontally towards and away from the wire W, and the drip tray 8 is provided with an adjustable blade 9 as already mentioned.

In order to protect the discharge tubes 2 from damage by accidental contact with the wire or misuse, they are surrounded by a stout grill of protective bars 14.

The embodiment shown in FIG. 3 has four discharge tubes 2 arranged in vertically spaced relationship on opposite sides of the line of movement wire W. The tubes 2 on one side are staggered with respect to those on the other side so that the respective jets do not interfere with each other to disturb the non-turbulent flows.

In FIG. 3, components having functions similar to those in FIG. 2 bear the same reference numerals and the operation of this embodiment being substantially identical to the embodiment of FIG. 2. Positional adjustments similar to those in the embodiment of FIG. 2 are provided.

The embodiments shown in FIG. 2 and 3, characterised by the use of a multiplicity of spaced single water jets, have been found to result in very effective cooling. Adequate contact time is provided between the wire and jets, and although an insulating steam jacket tends to develop around the wire in each jet, the steam can escape in the spaces between jets.

The embodiment shown in FIG. 4 incorporates three sub-sets of jets, each sub-set comprising the combined streams from a linear array of four discharge tubes 2. The flow in each discharge tube 2 is individually adjusted by, for example, pinching the tube or obstructing the flow in or to the tube 2 so that the individual streams combine smoothly into one jet having a large height relative to its width and having a non-turbulent flow. The degree of pinching or obstruction of each tube 2 is generally graded so that the tube that is lowest in each sub-set has the most restriction or obstruction while the tube highest in the sub-set has the least restriction or obstruction. In this way, the streams issuing from the discharge tubes 2 are adjusted to form one non-turbulent jet of water. The water catch trough 7 is shown with splitters 15 which can be beneficial in minimising splashing. The construction and operation of the primary quench of this embodiment is otherwise identical to that of the previous embodiments.

The embodiment shown in FIG. 5 incorporates a single jet comprising the combined streams from eight discharge tubes arranged in a vertical linear array and including two sub-sets of four tubes supplied from two manifolds 3. The lowest tube in each sub-set comes from the highest position in the manifold, thus at least partially equalising the hydrostatic heads and hence the flow rates in the tubes. The construction and operation is otherwise as in the embodiment of FIG. 4.

FIG. 6 illustrates the use of a single water jet which is approximately coaxial with the line of movement of the wire for a large part of its height. The jet flows in the direction of wire movement from a relatively large discharge tube 1 which is upwardly inclined at about 60° to the line of wire movement, the jet therefore being partly maintained by the movement of the wire W.

At the top of the jet, the water is entrained in a transversely directed air stream and swept into the liquid recovery tube 16 which is connected to a suction fan 17 via a vessel 18. The water accumulates in the vessel until the hydrostatic head is sufficient to overcome the suction. Then it automatically discharges through the outlet 19 and is recovered for re-use.

Typically, the coaxial jet has a height of 75 mm to 100 mm. Naturally, several jets could be used arranged along the length of the wire.

As in previous embodiments, an air curtain and an air jet would be used to minimise the amount of water that falls into the wiping bed but these items are not shown in the figure.

Our experiments indicate that the embodiments shown in FIGS. 4, 5, and 6 have a somewhat lower cooling efficiency owing to the absence of the relatively large number of spaces between jets for the escape of steam which are a characteristic of the embodiments shown in FIGS. 2 and 3.

It will be appreciated that one or more of the sub-sets of tubes 2 shown in the embodiments of FIGS. 2 and 3 may be replaced by a sub-set as shown in FIG. 4 or by the arrangement shown in FIG. 5. Similarly one of the sub-sets in FIG. 4 may be replaced by one or more of the sub-sets of FIGS. 2 and/or FIG. 3.

A preferred form of water discharge tube 1 having a bore of rectangular cross-section is shown in FIG. 7. The tube is shown directed upwardly at an angle of about 45° to the vertical and the end of the tube cut at a similar angle with its end face parallel with the wire W. For wires up to about 3 mm in diameter, a sufficiently wide jet is obtained from a single tube having a rectangular bore 11 mm × 4 mm, the wall thickness conveniently being about 1 mm. Each tube is arranged with its larger dimension oriented transversely of the wire. In the region of the intersection with the wire, the jet width is about 13 mm. For wires having a diameter greater than about 3 mm and at very high speeds, two discharge tubes are preferably used side by side as shown in FIG. 8. A water flow rate of about 2.2 litres per minute per tube has been found to give good results.

For quenching a number of parallel wires simultaneously, which is the usual case in practice, the jets cooling adjacent wires may be combined into a single wide jet. In this case, there would be a corresponding increase in the number of adjacent tubes seen in plan. Instead of using an assembly of individual tubes, a unitary fabricated or cast construction can be used, which provides an equivalent number of discharge passages, each having a bore of rectangular cross-section. This modification may be applied also to the embodiments of FIGS. 2 to 5.
In the embodiments shown in FIGS. 2, 3, and 4, the use of a wide jet embracing a number of wires would be most appropriate in the lowest position, so as to carry away drips and splashes from jets situated higher up.

I claim:

1. An apparatus for cooling and solidifying coatings on moving wires, the coating having been applied by a coating apparatus from which the wire passes upwardly, comprising at least one liquid discharge passage for forming a jet of cooling liquid intersecting the line of movement of the wire from the coating apparatus, at which point the coating is still in the liquid state, and having a height substantially greater than its width, means for controlling the jet issuing from said at least one passage whereby the flow of liquid is non-turbulent so that the coating is solidified while it remains substantially smooth and uniform, and an air discharge duct having a horizontal narrow discharge slit for creating a flow of air directed transversely to the line of movement of the wire between the cooling apparatus and the coating apparatus for preventing the entry of cooling liquid into the coating apparatus.

2. An apparatus according to claim 1, wherein at least two passages are arranged in a linear array positioned along the line of movement of the wire said passages having their discharge ends adjacent each other whereby the individual streams merge into a single non-turbulent jet having a height greater than its width, said jet being directed transversely to the line of wire movement in the region of intersection with the wire.

3. An apparatus according to claim 1, wherein a single discharge passage forms a non-turbulent jet of water flowing in the direction of wire movement, said jet being coaxial with the line of wire movement for a large part of its height, a liquid recovery tube spaced from said passage in the direction of wire movement and having its axis directed transversely to the line of wire movement, suction means connected to the recovery tube for creating a stream of air into the tube and into which said jet is entrained.

4. An apparatus according to claim 2, wherein there are several linear arrays of discharge passages arranged in spaced relation along the line of movement of the wire, the passages in each array being restricted or obstructed to a different degree whereby the individual streams from the passages combine to form a single non-turbulent jet.

5. An apparatus according to claim 2, wherein the discharge passages in said array are arranged one above the other, said passages being connected to a water supply manifold with the lowermost passage at the discharge end being the uppermost passage at the manifold, each passage being restricted or obstructed to a different degree whereby the individual streams from the passages combine to form a single non-turbulent jet.

6. An apparatus according to claim 1 wherein, said at least one discharge passage has a rectangular bore, the major dimensions of the bore being oriented transversely of the direction of wire movement.

7. An apparatus for cooling simultaneously the coatings on several parallel wires in substantially the same plane, comprising a plurality of cooling apparatus as defined in claim 1 arranged side-by-side, the streams in said apparatus being laterally merged into a single jet.

8. An apparatus for cooling and solidifying coating on moving wires, the coating having been applied by a coating apparatus from which the wire passes upwardly, at least two liquid discharge passages for forming jets of cooling liquid spaced along and transversely intersecting the line of movement of the wire from the coating apparatus, at which point the coating is still in the liquid state, means for controlling the jets issuing from said passages whereby the flow of liquid in each jet is non-turbulent so that the coating is solidified while it remains substantially smooth and uniform, and an air discharge duct having a horizontal narrow discharge slit for creating a flow of air directed transversely to the line of movement of the wire between the cooling apparatus and the coating apparatus for preventing the entry of cooling liquid into the coating apparatus.

9. An apparatus according to claim 8 wherein said liquid discharge passages are arranged on both sides of the line movement of the wire and are staggered with respect to each other whereby the jets impinge on both sides of the wire and the respective jets do not interfere with each other.

10. An apparatus according to claim 8 wherein at least two discharge passages have rectangular bores, the major dimensions of the bores being oriented transversely of the direction of wire movement.

11. An apparatus for cooling simultaneously the coatings on several parallel wires in substantially the same plane, comprising a plurality of cooling apparatus as defined in claim 8 arranged side-by-side, the streams in said apparatus being laterally merged into a single jet.

12. An apparatus for cooling simultaneously the coating on several parallel wires in substantially the same plane, comprising a plurality of cooling apparatus according to claim 8 arranged side-by-side, the lowermost streams being laterally merged into a single jet.

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