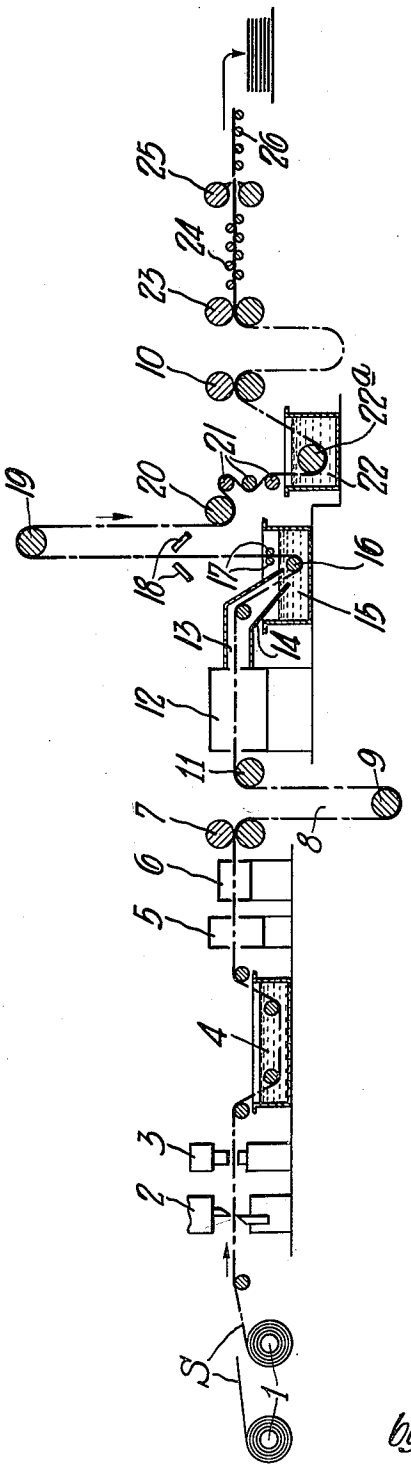
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CONTINUOUSLY PROCESSING FERROUS STRIP OR SHEET MATERIAL

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CONTINUOUSLY PROCESSING FERROUS STRIP OR SHEET MATERIAL

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This invention relates to an improved treatment for ferrous material, such as low-carbon steel, to substantially reduce the tendency to form flutes, coil breaks and stretcher-strains during the subsequent handling or forming thereof, and more particularly to continuous annealing or continuous annealing and hot-dip coating of low-carbon, deep-drawing sheet or strip material.

Low-carbon steel sheet or strip, either coated or uncoated as the ultimate use dictates, is widely used in the fabrication of many articles of commerce. In most instances, the fabrication involves the forming or drawing of the material. The appearance and, in many cases, the utility of the article, depends upon the formed or drawn parts of the article being free of surface irregularities. To accomplish the forming or drawing easily, the steel must be in the annealed i. e. softened, state.

It is well known that annealed low-carbon steel has the unique property of yielding abruptly and markedly under stress and then continuing such local deformation under the same or a stress lower than that required to cause the first plastic flow. This behavior is responsible for the characteristic shape of the stress-strain curve of annealed low-carbon steel. It is also responsible for the defects termed "stretcher-strains" or "worms" which occur during stamping or drawing operations, and for defects known as "flutes" or "coil breaks" which form when the material is subjected to operations involving bending. Flutes and coil breaks are localized stretcher-strains. They are sharp, permanent creases or kinks. Coil breaks are flutes that occur during the handling of strip material through looper pits, over deflector rolls, or in a coiling operation. Fortunately, this shortcoming of annealed low-carbon steel sheet or strip is overcome by very slight cold deformation which substantially eliminates the excessive elongation at the yield point with the result that stretcher-strains and flutes will not occur. This is most commonly accomplished by pinch passing or temper rolling, both of which are forms of cold rolling involving extremely slight reductions.

Somewhat similar effects are obtained by roller leveling, which operation has certain peculiar advantages. There is no appreciable increase in the hardness, nor is there a detectible change in the thickness of the material when this method is used since the sheet or strip is merely bent backward and forward by passing it over staggered rolls. Undesirable hardening of the material, which is of extreme importance for some applications, could thus be avoided. Roller leveling is also simpler and cheaper than the other methods, both from the standpoint of initial equipment and operation.

Unfortunately, however, full utilization of the

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advantages of roller leveling has never been attained because "fluting" of the annealed low-carbon sheet or strip occurs when the material is subjected to the initial bending operation involved in roller leveling. Consequently, it has heretofore been necessary to temper roll prior to roller leveling.

The fact that flutes can only be prevented by cold rolling has proven a serious handicap in the continuous annealing of long sheets or strips of low-carbon steel, and it has been a particularly serious handicap in continuous hot-dip coating processes in which continuous annealing is an essential step. In such processes, in order to prevent flutes, it has been necessary to resort to oversize deflector rolls in handling the strip after it has been annealed, and in addition since rolling equipment is not adapted to "in line" operation in these processes, it has also been the practice to coil on an oversize mandrel and transfer the coils to another section of the mill for temper rolling. These expedients have made such processes unduly costly and unattractive commercially. Moreover, in the case of coated product, the rolling has an objectionable effect on the appearance of the coating.

It is accordingly an object of this invention to provide ferrous sheet or strip material having a reduced tendency to flute.

It is another object to provide continuously annealed low-carbon, coated or uncoated sheet or strip material which can be roller leveled without temper rolling.

It is a further object to provide an improved method of reducing the tendency to stretcher-strain in annealed low-carbon sheet or strip material.

It is still another object to provide an improved method of continuously annealing or continuously annealing and hot-dip coating low-carbon sheet or strip material.

The foregoing and further objects will become apparent from the following specification when read in conjunction with the attached drawing, wherein is shown a schematic view of a continuous hot-dip coating line embodying the principles of this invention.

It is well known that (1) when annealed low-carbon steel is subjected to a standard tensile test the stress-strain curve shows considerable elongation occurring as the metal passes from the elastic to the plastic state and that a steel which exhibits this marked yield point elongation will flute when bent and will stretcher-strain when drawn; (2) when annealed low-carbon steel is tensile tested at elevated temperatures, yield point elongation decreases as the temperature of testing is raised into the blue heat zone; and (3) when an annealed low-carbon sheet is slightly cold worked, i. e., temper rolled or temper rolled and roller leveled so as to avoid

flutes and/or stretcher-strains during subsequent operations and is then subjected to the standard tensile test, the yield point elongation is entirely or substantially eliminated. Thus it would appear that annealed low-carbon steel could be worked in the blue heat zone without the coincidental appearance of flutes.

However, it is equally well known that annealed low-carbon steel must be temper rolled at a temperature below 180° F. since above this temperature the operation is ineffective insofar as preventing stretcher-strains is concerned, i. e., annealed low-carbon steel temper rolled at 200° F. will revert to the stretcher-strain condition in a matter of minutes. Moreover, the prior art is quite definite in its teachings that working in the blue heat zone must be avoided since hardening and embrittlement result therefrom.

The basis of the present invention lies in the discovery of conditions under which annealed low-carbon steel can be worked in the blue heat zone without an attendant increase in hardness or in brittleness and under which the effects of this work can be made to persist so that the natural tendency of the material to flute at room temperature is substantially eliminated.

In its broadest concept, the present invention comprises working a ferrous metal sheet or strip, of the type which is subject to the formation of flutes when bent at room temperature, as follows: (1) the material is stressed through its yield point by bending or flexing, i. e., the stressing is done in a manner such that the rate of stressing is, for all intents and purposes, infinitely fast; (2) the bending or flexing is done at a temperature of at least 350° F. but below 500° F.; and (3) the metal is immediately quenched from the working temperature to a temperature of at least 150° F. as rapidly as possible. Material treated in the foregoing manner will have its tendency to coil break or flute substantially eliminated; its tendency to stretcher-strain materially reduced; and contrary to the teachings of the prior art will not be appreciably hardened nor embrittled despite its being worked in a zone which is considered as causing great hardening.

In explanation of the new treatment, it is well known that low-carbon steel, when slightly strained has a tendency to age harden and to revert to the stretcher-straining condition. The rate of age hardening is known to increase rapidly with the temperature, e. g., the rate of age hardening at room temperature can be measured in weeks; at the boiling point of water, age hardening becomes a matter of minutes; at about 400° F. it is a matter of seconds; and in the neighborhood of 600° F. aging becomes practically instantaneous. In the present invention the annealed low-carbon steel at 350°–500° F. is stressed through the yield point by passing it around a roll or rolls of suitable diameter. Under these conditions, the rate of stressing is practically instantaneous and although the rate of aging is quite rapid it is nevertheless sufficiently slow that an appreciable time at temperature is required for aging to adversely affect the mechanical properties of the metal. Thus by quenching the metal immediately after the flexing, aging is arrested and its effects, increased hardness and embrittlement, are avoided.

The maximum temperature at which the flexing can be done is about 500° F. for ordinary low-carbon deep-drawing stock. Above this temperature the rate of age hardening becomes so rapid that the quenching is ineffective. The

minimum temperature of flexing is 350° F.; below this temperature fluting of the material cannot be avoided with certainty upon application of the initial bending stresses. The flexed material must be rapidly quenched to a temperature of at least 150° F. since above this temperature aging can still proceed at a sufficiently rapid rate to adversely affect the hardness and other properties of the metal. A sufficiently rapid quench to prevent age hardening can be obtained in most instances by sprays or immersion in water maintained at below 150° F.

The method is equally effective in processing either hot-rolled or cold-reduced sheet or strip material. The annealing conditions used in conjunction with it are not critical but depend only upon the mechanical properties desired in the annealed product. The speed of travel of the sheet or strip during treatment is not critical but depends only upon the limitations of the equipment used in the annealing or the annealing and coating operations. The gage of the sheet or strip material is not critical except in the amount of flexing or working which light and heavy gages must be given, as will be described later.

As previously stated, the mode of working used in practicing this invention is bending or flexing the material over a roll or rolls. This requires very simple, low-cost equipment, presents no technical problems either in design or operation, and is adapted to in line operation in a continuous process. The stresses applied must be sufficient to cause yielding in at least the outer fibers of the sheet or strip. The diameter of the roll therefore is critical with respect to the gage of the material being treated.

The maximum roll diameter which can be used successfully is 500 times the thicknesses of the material, i. e., if the material being processed is 0.072 inches in thickness, the maximum diameter of the roll which could be used is 36 inches; if the thickness of the material is 0.020 inches, the maximum roll diameter is 10 inches.

In general, decreasing the size of the roll tends to increase the hardness and lower the ductility of the product. The increase in hardness and loss of ductility, however, is very gradual, for example, when processing 0.072 inch strip, the roll diameter can be decreased from 36 to 10 inches without significant change in hardness or ductility of the metal. Thus a single roll size can be used to process a wide range of strip thicknesses, for example, a 10-inch roll can be used to process strip ranging in the thicknesses from 0.020 inches to 0.072 inches. A major part of the material used for deep-drawing falls within this range.

While the method of the present invention can be practiced using a single roll, it is preferable to use two or even three rolls in the form of a cluster or bridle. This provides reverse bending the sheet or strip at least once while within the specified temperature range. Reversing the bending action is desirable since the material is thereby worked more uniformly.

So far the detailed description of the method has been concerned with working the material at an elevated temperature whereby fluting is prevented both during the initial working and during any subsequent working at ordinary temperatures. The stretcher-straining tendencies of steel sheet or strip are also reduced by the treatment, but are not completely eliminated. Material so treated can be used without further treatment in any application in which freedom from fluting during bending is the main require-

ment. Where substantially complete freedom from stretcher-strains is required, the material must be further worked at substantially room temperature, i. e., below 150° F. The present invention permits such working to be done by roller leveling without first pinch passing or temper rolling prior to such operation. As previously mentioned, the latter is of particular importance in the continuous annealing of deep-drawing strip material or in continuous annealing of such material followed by hot-dip coating.

In addition, there are indications that material processed at the elevated temperature as described and then further processed as by roller leveling to eliminate stretcher-straining will retain the last condition for much longer periods of time than that processed in the normal manner, namely, by light temper rolling or temper rolling followed by roller leveling. This is an added advantage of the method over the considerable savings in costs which it effects.

Roller leveling is essentially a bending operation. Its primary objective is to flatten the material. Where extreme flatness is not a primary requirement of the product, a simple cluster of two or three rolls can be used in place of the roller leveler to achieve substantially complete freedom from stretcher-strains. This would be advantageous from a cost standpoint, since the roller leveler is of necessity of a precision machine. Moreover, larger diameter rolls with a consequent saving in power can be used in the simple cluster arrangement than can be designed into a roller leveler. While more than three rolls can be used without deleterious effect, no advantage is gained by the use of additional flexing.

With either roller leveling or simple flexing, the objective of substantially complete elimination of the tendency to stretcher-strain may be obtained without appreciable increase of hardness or undue loss of ductility.

As is the case when flexing the sheet or strip material at the elevated temperature, the roll diameter is also critical when flexing at substantially room temperatures. It has been found, however, that much smaller rolls are required at the latter temperatures. Whereas, flexing 0.072 strip over a 36-inch diameter roll at a temperature within the 350° to 500° F. range is sufficient to eliminate fluting, flexing this material over an 8-inch roll at room temperature does not work the metal sufficiently to provide substantial freedom from stretcher-strains. Experiment has shown that the maximum roll diameter for the latter purpose is 6 inches for this gage, or no more than 100 times the thickness. Smaller rolls, of course, can be used.

In designing a cluster of rolls for flexing sheet or strip in the manner set forth above, it is necessary to provide for positive contact of the material around a substantial portion of the roll surface, the minimum being about two inches of the periphery of the roll. Provision must also be made to maintain the material under sufficient tension to maintain this positive contact. In addition, in apparatus for flexing at room temperature, the third roll or the last, if more than three are used, should be adjustable so that a portion of the set put in the strip by the action of the preceding roll can be removed and the strip or sheet delivered from the apparatus reasonably straight. The mechanics of such adjustment are well known in the art.

The principles of the present invention are particularly applicable to the continuous annealing

or the continuous annealing and hot-dip coating of low-carbon steel strip and when so applied provide improved methods for conducting these operations. Such a preferred embodiment of the invention is shown in attached drawing, wherein a strip S of low-carbon steel is shown being pulled from one of a pair of uncoilers 1, through a squaring shear 2 and welder 3 into a tank 4, which contains a suitable alkaline degreasing solution, through a hot water and spray rinse unit 5 and a hot-air drier 6, by a pair of power-driven pinch rolls 7. The pinch rolls 7 feed the strip into a loop or slack producer 8 and around a dancer roll 9 which, in conjunction with electrical control equipment, not shown, maintains a desired length loop in the looper and a desired strip tension in the subsequent sections of the processing line. The strip is pulled from the looper by a drive bridle or power-driven pinch roll 10 located near the end of the processing line. The strip passes upwardly from the looper over deflector roll 11 into an annealing unit consisting of a heating zone 12 and a cooling zone 13. A reducing or non-oxidizing atmosphere is maintained in the annealing unit to prevent the formation of scale or oxide during annealing. The cooling zone 13 is equipped with a conduit 14 which extends below the level of the molten coating metal, such as zinc, contained in the pot 15. The strip S passes downwardly through this conduit and is introduced into the molten coating metal without contact with air. The strip passes around a sink roll 16 whish directs the strip through a pair of finishing rolls 17, and a cooling device 18, which directs a blast of cold air against the surfaces of the strip. It then passes over a deflector roll 19 which directs the strip downwardly toward a deflector roll 20 and then over a set of flexing rolls 21 into a quench tank 22 around a sink roll 22*a* to the drive bridle 10 previously mentioned. The drive bridle 10 discharges the strip into a small free loop so as to permit the strip to be laterally positioned by side guides, not shown. The strip is pulled from the loop by a pair of power-driven pinch rolls 23 which feed the strip to a roller leveler 24 to a flying shear 25 which cuts the strip into sheets of the desired size. The cut sheets are moved by a conveyor 26 to a suitable piler mechanism, not shown. The pinch rolls 7 and 23, the drive bridle 10 and the motor of the flying shear 25 are supplied with power from a common source and with individual controls whereby the movement of the strip through the various sections can be synchronized. Electrical equipment for this purpose is well known and is therefore not shown.

The processing is made continuous by joining the head end of a new coil to the tail end of a preceding coil by means of the welder 3. The ends of the coils are squared prior to welding by shear 2. The loop 8 is provided to permit the welding to be done without disturbing the subsequent annealing and coating operations. The aqueous alkaline solution used in the degreasing step can be made up of any efficient water soluble alkaline salts for removing oil and grease from metallic surfaces. The cleaning may be done either with or without the aid of electric current depending upon the nature of the foreign material to be removed. It is important to remove all carbonaceous substances, such as oils and grease from the material to be annealed since such carbonaceous substances when heated will pollute the atmosphere in the

annealing furnace and promote surface reactions on the steel which impair the adherence of the hot-dip coating subsequently applied. The material handled through the process is either hot rolled and pickled or hot rolled, pickled and cold reduced. In either condition, it is substantially free of oxides. It is important that this freedom from oxides be maintained throughout the annealing and coating operation. To insure this, a reducing or non-oxidizing atmosphere is introduced near the exit end of the annealing unit and is caused to flow backward in a direction counter to that of the strip movement. The temperature maintained in the annealing furnace depends chiefly upon the properties desired in the base metal. In some instances, subcritical or low temperature annealing is sufficient, in others the annealing temperature must be maintained high enough to produce a normalized structure.

The cooling section of the annealing unit should be so designed to permit both a controlled cooling rate and discharge temperature. It is important to regulate the temperature of the strip entering the molten metal coating bath in order that the fullest economies of the process and the optimum conditions for coating be realized. Introducing the metal into the coating bath at an elevated temperature promotes uniform wetting of the base metal by the coating metal and utilizes the sensible heat of the strip to the greatest possible extent. High bath temperatures, however, increase the tendency for the formation of iron zinc alloy or dross in the coating since the presence of this material contributes to rough coatings and the loss of adherent coating. For this reason, the temperature of the strip entering the bath should be held as nearly as possible to the minimum below which heat losses from the bath would have to be supplied from an outside source.

The best furnace discharge temperature for the best metallurgical functioning of the operation will vary somewhat depending upon the composition of the base metal and composition and operating characteristics of the coating bath. For example, a zinc bath containing 0.10% aluminum operates most satisfactory at a temperature of about 850° F. For a given coating pot, a base metal temperature can be determined within this range which will maintain the coating bath at its optimum operating temperature without the use of external heaters. For coating metals other than zinc, a different base metal temperature will be found at which optimum operating conditions are maintained. This temperature may vary from approximately 450° F. in the case of tin to 1218° F. or higher in the case of aluminum. In general, the entering base metal temperature should be only slightly higher than the operating temperature of the coating bath.

The cooling zone of the furnace must also be equipped to equalize the cooling rates for heavy and light gage material. It is obviously necessary to remove more heat from heavy gage material than from light gage material at the same processing speed. Actually, however, light gage material can be processed at much higher line speeds than heavy, but the heating and cooling characteristics of various gages are such that specific regulation is required even though the weight of material being treated were kept constant. Thus, it may actually be necessary to apply external heat to the cooling chamber when processing light gage material while cooling may be necessary when processing heavy gages. In any event, it is necessary to avoid "quenching effects" and resulting inferior physical properties.

After such annealing, the material is in condition to be coated. The success of this step depends upon preventing contact of the strip with air prior to entering the bath. To accomplish this, the exit end of the cooling chamber may be extended into the molten metal and the protective effect of the non-oxidizing or reducing atmosphere in the annealing furnace can thus be extended to the surface of the molten metal at the point where the strip enters the coating pot. In this manner, both the surface of the coating metal adjacent the entering strip and the surface of the strip are maintained free of all oxides, thus complete wetting of the coating metal is obtained.

In the preferred embodiment herein described, the coating metal is zinc to which has been added 0.05 to 0.30% aluminum by weight, to promote fluidity and retard the alloying action of the zinc with the base metal. The use of wet or molten fluxes, either applied to the surface of the strip material or the surface of the molten coating bath, must be avoided, since the ordinary chloride fluxes react with the aluminum of the bath and rapidly remove it from the bath.

The strip material is preferably removed from the bath in a vertical pass line to promote uniformity of coating. Conventional finishing rolls may be used to regulate the weight of coating. Cooling means such as an air blast is generally necessary and should be provided at some predetermined point above the surface of the bath, the exact location depending upon the type and size of spangle finish desired. The cooling means also serves to lower the temperature of the strip to within the blue heat range and preferably within the preferred range of 350° to 500° F. for the flexing step. It is obvious that the strip temperature must be decreased below the freezing temperature of the coating metal prior to contacting flexing roll or rolls.

The flexing roll or rolls are preferably located in the horizontal pass line of the strip after passing around the deflector roll 21. As hereinbefore described, a cluster of three 10-inch diameter rolls is satisfactory for the majority of gages which are hot-dip galvanized. The passage of the strip over these rolls substantially eliminates the tendency of the material to flute as it passes through subsequent equipment in the processing line while cooling to room temperature.

Coated strip at this point in the process could be used for any application in which absence of fluting during forming is the main requirement. If it is desired, however, to produce material of the highest quality which will not stretcher-strain even under the most severe condition of deep-drawing, the strip can be processed by cold working as described at substantially room temperature. In the example shown, roller leveling, which also serves to flatten the strip, has been described as a satisfactory means of supplying the necessary cold work. If flattening is not essential, a simple 3-roll bridle, similar in construction to the hot flexing bridle previously described, can be substituted for the roll leveler.

It is of course obvious that similar equipment

for uncoiling, annealing, cooling, flexing, transporting while cooling to room temperature, and final flexing, can be used to produce annealed product without coating. Thus for merely annealing the equipment may be substantially as that described for annealing and coating, except that no coating pot is provided and the strip need not be moved vertically unless it is desired to save space.

While a preferred embodiment of the invention has been shown and described, it will be understood that this embodiment is merely for the purpose of illustration and description and that various other forms may be devised within the scope of this invention, as defined in the appended claims.

I claim:

1. A method of treating ferrous metal to substantially eliminate fluting thereof comprising bringing the metal to a temperature within the range of 350 to 500° F.; working the metal while in said range, said working being regulated to stress at least the outer fibers of the metal through the yield point thereof; and immediately quenching the worked metal to at least 150° F.

2. A method of treating low carbon steel sheet or strip material to substantially eliminate fluting thereof comprising bringing such material to a temperature within the range of 350 to 500° F., flexing the material while in said range through an arc of sufficiently small diameter to strain at least the outer fibers of the material through the yield point thereof, and immediately quenching the stressed material to at least 150° F.

3. A method of treating low carbon steel sheet or strip material to substantially eliminate fluting thereof comprising bringing such material to a temperature within the range of 350 to 500° F., flexing the material while in said range through an arc having a maximum diameter of 500 times the thickness of the material, and immediately quenching the stressed material to at least 150° F.

4. A method of producing annealed low carbon steel sheet or strip material free of the tendency to flute when flexed or bent comprising annealing such material, cooling the annealed material to a temperature within the range of 350 to 500° F., stressing the material while in said range sufficiently to cause yielding in at least the outer fibers thereof, and immediately quenching the stressed material to at least 150° F.

5. A method of treating low carbon deep drawing steel sheet or strip material to substantially eliminate stretcher straining thereof during subsequent forming operations comprising bringing such material to a temperature within the range of 350 to 500° F., working the material while in said range sufficiently to cause yielding in at least the outer fibers thereof, immediately quenching the stressed material to at least 150° F., and then further working the material at a temperature below 150° F., said last mentioned working being regulated to again stress at least the outer fibers of the material to the yield strength thereof.

6. A method of treating low carbon deep drawing steel sheet or strip material to substantially eliminate stretcher straining thereof during subsequent forming operations comprising bringing such material to a temperature within the range of 350 to 500° F., flexing the material while in said range through an arc of sufficiently small diameter to cause yielding in at least the outer fibers of said material, immediately quenching the stressed material to at least 150° F., and then flexing the material through an arc of sufficiently small diameter to cause yielding of at least the outer fibers while at a temperature below 150° F.

7. A method of treating low carbon deep drawing steel sheet or strip to substantially eliminate stretcher straining during subsequent forming operations comprising bringing such material to a temperature within the range of 350 to 500° F., flexing the material while in said range through an arc having a maximum diameter of 500 times the thickness of the material, immediately quenching the stressed material to at least 150° F., and then flexing the material through an arc having a maximum diameter of 200 times the thickness of the material.

8. A method of treating low carbon deep drawing steel sheet or strip to substantially eliminate stretcher straining during subsequent forming operations comprising bringing such material to a temperature within the range of 350 to 500° F., flexing the material while in said range through an arc having a maximum diameter of 500 times the thickness of the material, immediately quenching the stressed material to at least 150° F., and then roller leveling the material.

9. A method of producing continuously annealed low carbon deep drawing steel sheet or strip substantially free of the tendency to stretcher strain in subsequent forming operations comprising heating such material as a strand to a temperature and for a time sufficient to anneal the same, cooling the annealed strand to a temperature within the range of 350 to 500° F., flexing said strand while in said range through an arc having a maximum diameter of 500 times the thickness of the strand, immediately quenching the stressed strand to at least 150° F., and then roller leveling the quenched strand.

10. A method of continuously hot-dip coating steel strip material, of the type normally having a pronounced yield point elongation at room temperature in the annealed condition whereby said metal has a definite tendency to flute when subjected to conventional roller-leveling operations comprising continuously annealing such material, continuously passing it through a bath of molten coating metal, cooling the coated metal to a temperature within the range of 350 to 500° F., passing said material while in said range into contact with a substantial portion of the peripheral surface of a roll of sufficiently small diameter to strain at least the outer fibers of said material through the yield point thereof, immediately quenching said material to at least 150° F. whereby said hot-dipped coated material can be roller leveled without fluting, and then roller leveling the material.

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