A strip flattening apparatus having a work roll and two reaction rolls which bear against the work roll to define a first and second nip. A pressure roll also contacts the work roll, loading it toward the reaction rolls so that there is more pressure at the first nip than at the second. Means are provided to cause the strip to enter the first nip at an angle of 2° - 20° to the tangent in the sense required to bend the strip about the work roll.
METHOD OF FLATTENING METAL STRIP EXHIBITING A DISCONTINUOUS YIELD POINT AND SUPPRESSING THE DISCONTINUOUS YIELD POINT

This invention relates to a method of flattening metal strip of the kind normally exhibiting a discontinuous yield point, and at the same time suppressing the discontinuous yield point of the material. In particular it may be used for annealed ferrous strip which for many applications is required to be flat, to have a good surface finish, and to be free from discontinuous yielding.

After cold rolling and annealing, metal strip often does not exhibit the degree of flatness required. This is evidenced by waviness in parts of the strip when it is laid on a flat surface, and by lateral curvature that may occur in narrow strips slit from a wider coil.

The principles involved in the roller-levelling of metal strip to obtain a flat product are well known and many types of levellers are available. However when metal strip exhibiting a discontinuous yield point is levelled in conventional levellers, a series of closely spaced coil breaks generally known as microfluting is formed in the strip. These are narrow bands of deformed material which run transverse to the levelling direction, and which are separated by bands of more or less undeformed material. Their formation is a consequence of the discontinuous yield point of the annealed material going into the leveller. After levelling the material may not exhibit a pronounced discontinuous yield point consequent upon the microfluting introduced by the leveller. However the microfluting pattern is objectionable in some products where surface finish is important, and it can also reduce the formability of sheet, particularly in the case of low carbon ferrous sheet which strain age harden in the deformed bands.

The problem of microfluting can be overcome by the known art of temper rolling the annealed strip prior to roller-levelling. A rolling extension of approximately 1 percent is sufficient to suppress the discontinuous yield point of the strip and thus prevent the formation of microfluting during subsequent roller-levelling. However this procedure necessitates two processes, two costly items of capital equipment, and is difficult to accomplish in a continuous annealing and galvanizing line.

An object of this invention is to provide a method and apparatus whereby a metal strip exhibiting a discontinuous yield, for example annealed ferrous strip, may be flattened without the formation of a microfluting pattern.

The invention attains that object by providing a novel roll arrangement which subjects the strip simultaneously to the combined effect of tensile, bending and compressive stresses whereby the compressive stresses control the yield behavior rather than cause yielding as in the case of temper rolling.

It is a further object of this invention that a microfluting-free flat strip is produced with only a small amount of plastic deformation to reduce deterioration in the mechanical properties of the strip by strain ageing.

According to one of its aspects, the present invention consists in a strip flattening apparatus comprising a work roll, a first reaction roll defining a first nip with said work roll, a second reaction roll defining a second nip with said work roll, means to draw a metal strip to be flattened through said nips and about that portion of the work roll between the nips while maintaining the strip under tension, at least one pressure roll contacting the work roll and loading it toward the two reaction rolls and means for determining the line of approach of the strip to the first nip such that the strip enters the first nip at an angle to the tangent within the range of from 2° to 20° in the sense required to bend the strip about the work roll; the arrangement being such that there is a greater reaction force between the work roll and the first reaction roll than there is between the work roll and the second reaction roll.

According to another aspect of the invention, it consists in a method of flattening and suppressing the discontinuous yield point of a metal strip, comprising the steps of bending the strip elastically while under longitudinal tension, and thereafter transversely compressing the strip while maintaining the bending and tensile loads thereon, in a manner such that the strip is simultaneously subjected to bending, longitudinal tension and through thickness compression.

So that the invention may be better understood a roll flattening apparatus in accordance with it is described hereinafter with reference to the accompanying single FIGURE diagram.

That diagram represents an end view of the rolls of a flattening apparatus, arranged in a disposition enabling the method of the invention to be put into effect.

When the invention is in operation the metal strip exhibiting a discontinuous yield point, is drawn through the flattening apparatus of the diagram under longitudinal tension which may be applied by tension bridles or any other conventional means. The average tensile stress within the strip, preferably lies between from 10 to 50 percent of the lower yield stress.

The strip passes around a work roll 1. Interroll pressure is applied to it between roll 1 and reaction rolls 2 and 3 by a pressure roll 5. The pressure on the strip in the nip of rolls 1 and 2 is high enough in conjunction with the bending stresses to deform the strip sufficiently to suppress the discontinuous yield. The interroll pressure between rolls 1 and 3 is less than that between rolls 1 and 2 and preferably is low enough so that no further rolling deformation occurs in the strip as it passes between rolls 1 and 3. The amount of plastic deformation of the strip can then be kept to the minimum required to produce flat strip free from microfluting. This will result in the least deterioration of mechanical properties.

The pressure between the inter-roll pressures applied to the strip in the two nips between rolls 1 and 2, and rolls 1 and 3, is preferably achieved by offsetting the pressure roll 5 by an angle α from the line bisecting the angle formed by lines passing through the centers of rolls 1 and 2 and rolls 1 and 3. The direction of this offset is such that the pressure applied to the strip between rolls 1 and 2 is larger than that between rolls 1 and 3. The magnitude of the offset angle α will depend on the difference in pressure required at the two nips, the roll diameters, their geometrical arrangement and strip tension. However it must be sufficiently small so that roll 1 operates in a stable configuration.

To minimize the rolling pressure, the strip preferably enters the leveller so that it makes an angle (α2) with the tangent to roll 1 at the nip between rolls 1 and 2. The stress state in the strip in this nip is one of com-
bined bending, longitudinal tension, and inter-roll or through thickness compression. Thus the inter-roll pressure required to deform the strip sufficiently to suppress the discontinuous yield point is lower than would be required by normal temper rolling practice. The angle \( \alpha_2 \) must be small enough so that the strip does not microflute before it reaches the nip of rolls 1 and 2. The angle therefore depends on strip thickness, yield stress, and the applied tension. The angle \( \alpha_2 \) will normally lie within the range 2° to 20°.

The inter-roll pressure between rolls 1 and 2 must be high enough so that in conjunction with the bending stresses existing in the strip at this pressure point, the material is deformed an amount sufficient to suppress the discontinuous yield point of the strip, at least in the surface layers. The required deformations usually result in extensions within the range 0.2 to 1 percent.

As the discontinuous yield in the strip has been suppressed between rolls 1 and 2, it will now bend uniformly around roll 1 without the appearance of microflutes, and roll 1 will act as the first flexing roll for the tension roller-leveler. Additional deformation at the pressure point between rolls 1 and 3 will only further work harden the strip without improving its appearance or flatness. Hence the offset angle \( \alpha_3 \) would normally be selected so that the pressure at this point would be sufficient to locate roll 1 without imparting further extension to the strip.

It is understood that this unit may be followed by subsequent flexing and/or levelling rolls in any configuration and with any number of subsequent rolls. These may be used to obtain further levelling action, or to remove coil set, otherwise known as cross-bow or gutter.

To obtain the required levelling action over roll 1, the ratio of its diameter \( d \) to the strip thickness \( t \) will usually be in the range of from 40 to 200, but values higher or lower may be required for specific applications. The diameter of the reaction rolls 2 and 3 would normally be in the range of from one to six times the diameter of roll 1. The reaction rolls may be of different diameters. Further back-up rolls 4 may also be required particularly when processing wide strip. The pressure and reaction rolls may be arranged using any suitable configuration and may be provided with means for bending if considered necessary and may be supported in such a way as to apply a uniform or any other desirable pressure distribution across the strip width between rolls 1 and 2.

We claim:

1. A strip flattening apparatus, comprising a work roll, a first reaction roll with its axis parallel to the axis of the work roll to define a first nip with said work roll, a second reaction roll with its axis parallel to the axis of the work roll to define a second nip with said work roll, means to draw a metal strip to be flattened through said nips and about that portion of the work roll between the nips while maintaining the strip under tension, at least one pressure roll contacting the work roll and loading it toward the two reaction rolls and means to control the line of approach of the strip to the first nip such that the strip enters the first nip at an angle to the tangent within the range of from 2° to 20° in the sense required to bend the strip about the work roll; the arrangement being such that there is a greater reaction force between the work roll and the first reaction roll than there is between the work roll and the second reaction roll.

2. Strip flattening apparatus according to claim 1, wherein the greater reaction force between the work roll and the first reaction roll by comparison with the reaction force between the work roll and the second reaction roll is caused by positioning a single pressure roll so that its axis lies to one side of the bi-sector of the angle between the lines joining the center of the work roll with the respective centers of the reaction rolls.

3. Strip flattening apparatus according to claim 1 in which the ratio of the diameter of the work roll to the thickness of the strip is within the range of from 40 to 200.