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Method and apparatus for surface strengthening of metal sheet/strip

CN117867240A | Published 2024-04-12

English translation for reference; original Chinese publication controls.

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Source: https://patents.google.com/patent/CN117867240A/zh

Application: 202311671657.6; filed 2023-12-07

Publication authority: China National Intellectual Property Administration; invention patent application

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IPC: C21D 7/02 (2006.01); C22F 1/00 (2006.01)

Translation notes

Complete English technical translation of the abstract, nine claims, all numbered description paragraphs and three drawings. TA34 is the material in Example 2; the apparatus and other example cover additional metals. The printed equations contain unusual notation and approximations; they are reproduced without technical correction and must be checked against the original before use. Formula numbering and the original S40 cross-reference are retained. Drawing geometry and reference numerals are retained; text labels are translated. Experimental results are not guaranteed TiHubs supply properties.

Abstract

The application discloses a method and apparatus for surface strengthening metal sheet/strip. Select the sheet/strip and obtain its parameters; input them into a target formula to obtain deformation parameters; install the bending rollers and adjust their relative positions; mount the sheet/strip and start a coiler at a preset speed; collect it after a bending cycle. Circular bending rollers impose pure bending rather than localized folding, avoiding nonuniform deformation. The inner side is compressed and the outer side is in tension. Longitudinal flow is small and thickness does not change appreciably, so the pure-bending zone produces more uniform deformation.

Claims

1. A method for surface strengthening metal sheet/strip, comprising: selecting the sheet/strip and obtaining its parameters; inputting the parameters into a target formula to obtain deformation parameters; installing bending rollers according to those parameters and adjusting their relative positions; installing the sheet/strip on the rollers and starting a coiler to draw it through at a preset speed; and collecting the sheet/strip after one bending cycle.

2. The method of claim 1, wherein the target formula is the N-pass equivalent strain epsilon_p = (2 alpha N/sqrt(3)) ln|2 delta/d|; d is roller diameter, N is roller count, delta is sheet/strip thickness, and alpha is overlap between adjacent rollers.

3. The method of claim 1, wherein the parameters include sheet/strip thickness.

4. The method of claim 1, wherein the relative positions are those of at least two bending rollers installed on the apparatus main body.

5. The method of claim 1, wherein installing the sheet/strip comprises wrapping it around adjacent bending rollers in opposite directions.

6. An apparatus using the method of any of claims 1-5, comprising a main body; at least two bending rollers rotatably and removably mounted on the main body; and coilers symmetrically arranged on both sides to wind the sheet/strip.

7. The apparatus of claim 6, further comprising at least two groups of leveling rollers rotatably mounted on the main body, with the bending rollers between the groups.

8. A computer-readable storage medium storing a computer program which, when executed, implements the method of any of claims 1-5.

9. A control apparatus comprising a memory for storing a computer program and a processor for executing that program, wherein the processor implements the method of any of claims 1-5 when executing the program.

Description

[0001] The application relates to metal surface treatment, and particularly to a method and apparatus for surface strengthening metal sheet/strip, a computer-readable storage medium and a control apparatus.

[0002] Large plastic deformation methods are widely recognized as effective means of refining metal grains and improving strength. Common methods include equal-channel angular pressing, high-pressure torsion, friction-stir processing and repeated bending/straightening. However, the equipment is demanding and the sample size is limited, making industrial application difficult.

[0003] Repeated folding can treat larger sheet, but requires many cycles and long processing times, and does not provide continuous production. Deformation is concentrated locally, so properties vary along the length. Local thinning, poor flatness and thickness fluctuations also impair subsequent processing.

[0004] (I) Technical solution

[0005] The principal technical solutions of the application are as follows.

[0006] In a first aspect, the application provides a method for surface strengthening metal sheet/strip.

[0007] The method comprises the following steps:

[0008] Select the sheet/strip to be strengthened and obtain its parameters.

[0009] Input those parameters into a target formula to obtain deformation parameters.

[0010] Install the bending rollers according to the deformation parameters and adjust their relative positions.

[0011] Install the sheet/strip on the bending rollers and start a coiler to draw it through at a preset speed.

[0012] After the sheet/strip completes one bending cycle, collect the material.

[0013] Optionally, the target formula is:

[0014] The equivalent strain after N passes is: epsilon_p = (2 alpha N / sqrt(3)) ln|2 delta / d| (1).

[0015] Here d is the roller diameter; N is the number of rollers; delta is the sheet/strip thickness; and alpha is the overlap between adjacent rollers.

[0016] Optionally, the parameters of the sheet/strip to be strengthened include its thickness.

[0017] Optionally, the relative positions of the bending rollers refer to the relative positions of at least two bending rollers installed on the main body of the apparatus.

[0018] Optionally, installing the sheet/strip to be strengthened on the bending rollers comprises:

[0019] Wrap the sheet/strip around adjacent bending rollers in opposite directions.

[0020] In a second aspect, the application provides an apparatus for surface strengthening metal sheet/strip.

[0021] The apparatus adopts the method of the first aspect and comprises:

[0022] A main body;

[0023] At least two bending rollers rotatably and removably installed on the main body; and

[0024] Coilers arranged symmetrically on both sides of the main body to wind the sheet/strip.

[0025] Optionally, the apparatus further comprises:

[0026] At least two groups of leveling rollers rotatably installed on the main body, with the bending rollers positioned between the two groups.

[0027] In a third aspect, the application provides a computer-readable storage medium.

[0028] The computer-readable storage medium

[0029] stores a computer program which, when executed, implements the method of the first aspect.

[0030] In a fourth aspect, the application provides a control apparatus.

[0031] The control apparatus comprises:

[0032] A memory for storing a computer program; and

[0033] A processor for executing the computer program;

[0034] when executing the program, the processor implements the method of the first aspect.

[0035] (III) Beneficial effects

[0036] The circular bending rollers cause pure bending rather than localized folding, avoiding nonuniform sheet/strip deformation. During bending, the inner surface is compressed and the outer surface is in tension. There is little material flow in the longitudinal direction and no appreciable thickness change. Pure bending therefore makes deformation more uniform and facilitates subsequent use. Multiple rollers provide repeated deformation and continuous processing, with industrial potential. The apparatus is relatively simple, deformation is convenient to analyze, and surface plastic strain can be adjusted through roller diameter and number, improving strengthening.

[0037] Figure 1 is a flow chart of the surface-strengthening method.

[0038] Figure 2 is a schematic of the geometric relationship of the bending rollers.

[0039] Figure 3 is a perspective view of the surface-strengthening apparatus.

[0040] Reference numerals in the drawings:

[0041] 100: main body; 200: bending roller; 300: coiler; 400: leveling-roller group; 500: traction roller.

[0042] Exemplary embodiments are described below with reference to the drawings. The application may take various forms and is not limited to the embodiments presented. These embodiments provide a thorough understanding and fully convey the scope to persons skilled in the art.

[0043] In a first aspect, as shown in Figure 1, a method for surface strengthening metal sheet/strip comprises:

[0044] S100: Select the sheet/strip to be strengthened and obtain its parameters.

[0045] In S100, these parameters include sheet/strip thickness.

[0046] S200: Input the parameters into the target formula to obtain deformation parameters.

[0047] In S200, the target formula is the N-pass equivalent strain: epsilon_p = (2 alpha N / sqrt(3)) ln|2 delta / d| (1). Here d is roller diameter; N is roller count; delta is sheet/strip thickness; and alpha is overlap between adjacent rollers.

[0048] For example, from the geometric similarity in Figure 2: (d/2)/x = (L_a - x)/(L_b - d/2) (2). Solving gives x = L_a/2 + sqrt((L_a^2 - d^2 + 2 d L_b)/4) (3). Accordingly, the actual bending angle is alpha = arctan (pi/180) ((sqrt(L_a^2 - d^2 + 2 d L_b) + L_a)/d) + pi (4). The original typeset expression is reproduced below because the placement of the angular factor is ambiguous. During bending, the strain at an elemental slice is epsilon = ln(r_p/r_0) (5), where r_p is the distance from the center of bending to an arbitrary elemental slice and r_0 is the distance from that center to the neutral plane: r_0 = (d + delta)/2 (6). Taking the sheet/strip surface of maximum accumulated strain as the reference gives r_p = (d + 2 delta)/2 (7). The accumulated strain in one bending pass is epsilon = integral from 0 to alpha of ln(r_p/r_0), approximately alpha ln|2 delta/d| (8). Thus the single-pass equivalent strain is epsilon_p = (2/sqrt(3)) epsilon = (2 alpha/sqrt(3)) ln|2 delta/d| (9). The N-pass equivalent strain is epsilon-bar = N epsilon_p = (2 alpha N/sqrt(3)) ln|2 delta/d| (10), namely formula (1).

$$\alpha = arctan\frac{\pi}{180}\left(\frac{\sqrt{L_a^2 - d^2 + 2dL_b} + L_a}{d}\right) + \pi$$

Equation (4), original typesetting retained. This mathematical expression has not been corrected or independently validated.

[0049] Here L_a is the vertical center-to-center distance of adjacent rollers and L_b is their horizontal center-to-center distance. A larger alpha means a longer deformation zone and greater accumulated strain in one pass. Greater sheet thickness produces greater accumulated surface strain. Smaller bending rollers 200 produce greater strain. Increased strain gives greater grain refinement and better overall properties.

[0050] S300: Install bending rollers 200 according to the deformation parameters and adjust their relative positions.

[0051] In step S40, the relative positions of bending rollers 200 mean the relative positions of at least two rollers 200 mounted on main body 100. [The original prints S40 here.]

[0052] S400: Install the sheet/strip on bending rollers 200 and start coiler 300 to draw it through at the preset speed.

[0053] In S400, the sheet/strip is wrapped around adjacent bending rollers 200 in opposite directions.

[0054] S500: After one bending cycle is completed, collect the material.

[0055] For example, determine the surface strain to be introduced from the selected material and desired strengthening effect, and determine the roller diameter, number and positions.

[0056] Install the bending rollers and adjust their positions.

[0057] Pull the 304 stainless-steel strip from the coil through the traction roller, wrap it around all bending rollers, pass it through the leveling rollers and secure it to the coiler.

[0058] Fix the traction roller, tighten the coiler, check the tension sensor and mark the strip 10 cm before the traction roller.

[0059] Release the traction-roller restraint, start the coiler at the selected speed and adjust the traction-roller tightness to maintain stable tension.

[0060] Stop the coiler, fix the leveling rollers, cut the strip 10 cm beyond the leveling rollers and anneal the collected strip.

[0061] Example 1: Continuous repeated bending and straightening using twenty rollers of 200 mm diameter, combined with simple annealing, increased the yield strength of 1 mm 304 stainless-steel sheet from 248 MPa to 305 MPa and its hardness from 212 HV to 285 HV.

[0062] Example 2: Continuous repeated bending and straightening using twenty rollers of 200 mm diameter, combined with annealing, increased the yield strength of 0.5 mm TA34 titanium-alloy strip from 645 MPa to 772 MPa. Both materials increased in strength without a marked change in plasticity, and their subsequent processing and use were not impaired.

[0063] Using circular rollers for pure bending avoids localized folding and nonuniform deformation. The inner side is compressed and the outer side is in tension, with little longitudinal flow and no appreciable thickness change. This produces more uniform deformation for later processing. Multiple rollers provide repeated deformation, continuous operation and industrial potential. The apparatus is relatively simple and convenient to analyze, and surface plastic strain can be controlled by roller diameter and number for improved strengthening.

[0064] In a second aspect, as shown in Figure 3, the apparatus comprises main body 100; at least two bending rollers 200 rotatably and removably mounted on it; and coilers 300 symmetrically arranged on its two sides to wind the strip.

[0065] The rollers are installed and their positions adjusted according to the deformation parameters; their rotatable installation enables the sheet/strip to pass through the apparatus.

[0066] The apparatus also includes at least two groups of leveling rollers 400, rotatably mounted on the main body, with bending rollers 200 between them.

[0067] In a third aspect, a computer-readable storage medium stores a computer program which implements the method when executed.

[0068] The storage medium has all the beneficial effects of the method.

[0069] The software product may be stored on a nonvolatile medium such as a CD-ROM, USB drive or removable hard disk, and includes instructions enabling a computer device, such as a personal computer, server or network device, to execute the method.

[0070] In a fourth aspect, the control apparatus includes a memory storing a computer program and a processor executing it to implement the method.

[0071] The control apparatus has all the beneficial effects of the method.

[0072] The control apparatus may also include a user interface, network interface, camera, radio-frequency circuit, sensor, audio circuit and Wi-Fi module. The user interface may include a display, keyboard, USB interface and card reader. The network interface may include wired and wireless interfaces.

[0073] The input/output and display units are connected through a bus. The memory stores the program and the processor executes it to implement the method.

[0074] The terms first and second are used only for description and do not indicate relative importance or imply the number of features. A feature so defined may include one or more such features. Unless expressly defined otherwise, a plurality means two or more.

[0075] Unless expressly limited, terms such as installation, connection and fixing are interpreted broadly: fixed, removable or integral; mechanical or electrical; direct or through an intermediary; internal communication or interaction. Their particular meaning is understood from the context.

[0076] A first feature above or below a second may contact it directly or through an intermediate feature. Above includes vertically or obliquely above, or simply higher; below includes vertically or obliquely below, or simply lower.

[0077] References to an embodiment, example or specific example mean that its particular features, structure, materials or characteristics are included in at least one embodiment or example. Such references do not necessarily refer to the same embodiment. Compatible features may be combined appropriately.

[0078] The embodiments are exemplary and do not limit the application. Persons skilled in the art may make changes, modifications, substitutions and variations within its scope.

Drawing

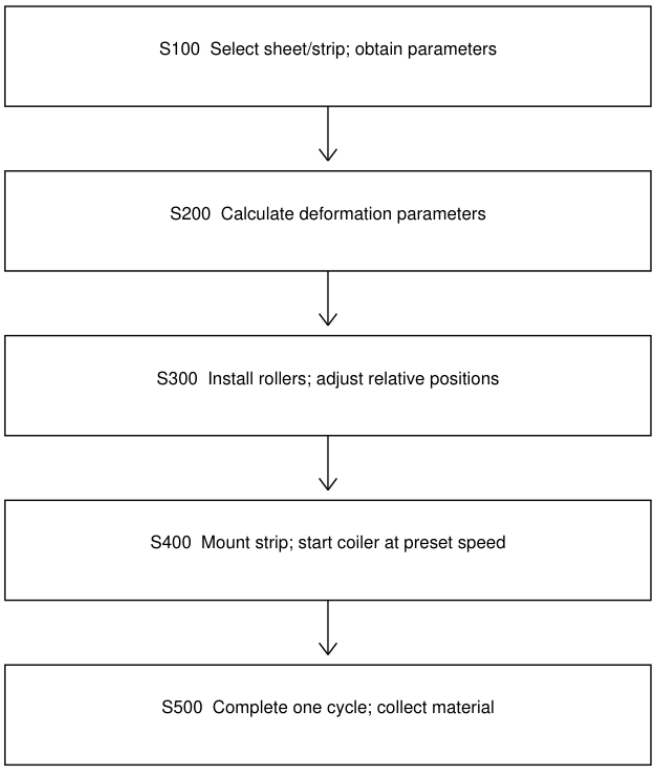


Figure 1. Method flow chart.

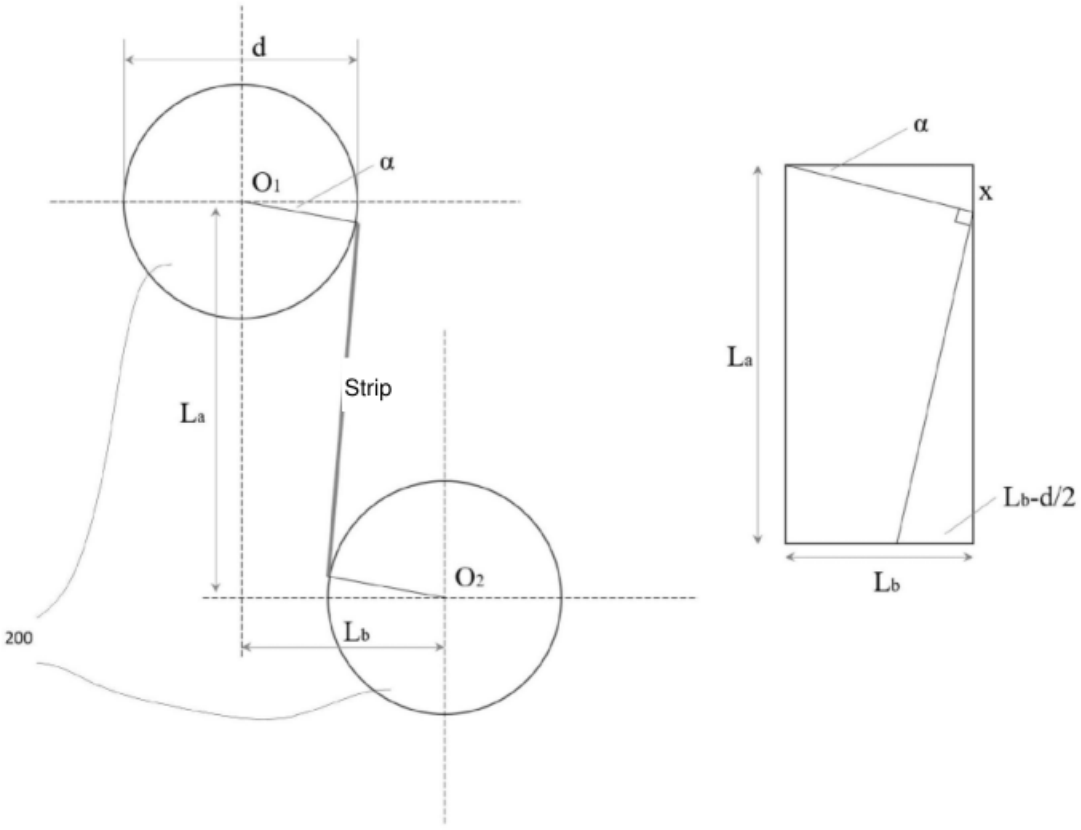


Figure 2. Geometric relationship of the bending rollers. d: diameter; delta: strip thickness (defined in text); alpha: bending angle; L_a and L_b: roller-center offsets.

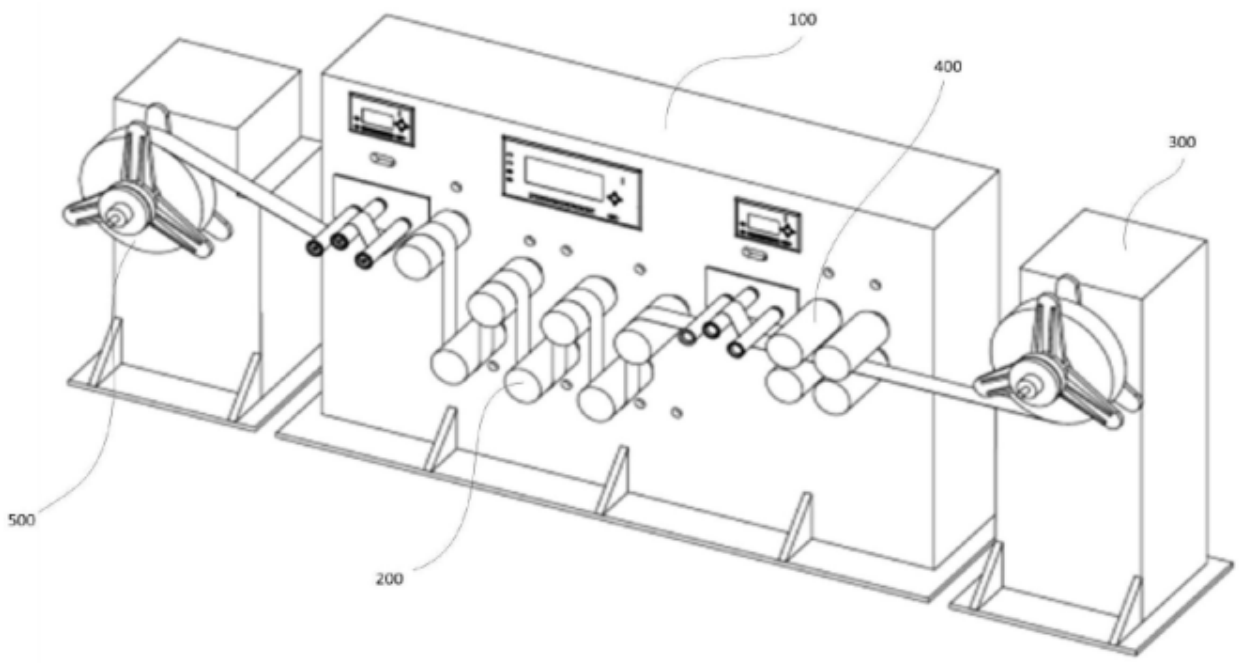


Figure 3. Surface-strengthening apparatus. 100 main body; 200 bending rollers; 300 coilers; 400 leveling rollers; 500 traction roller.