Sept. 16, 1969 J. MARCOVITCH 3,466,916

WORKING OF PLASTICALLY DEFORMABLE MATERIALS

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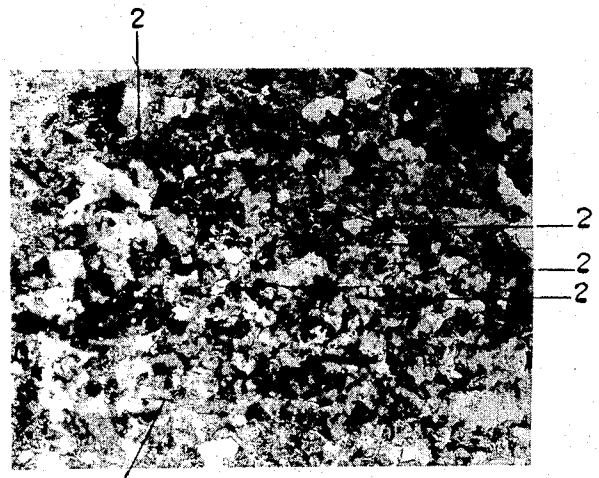


Fig. 1

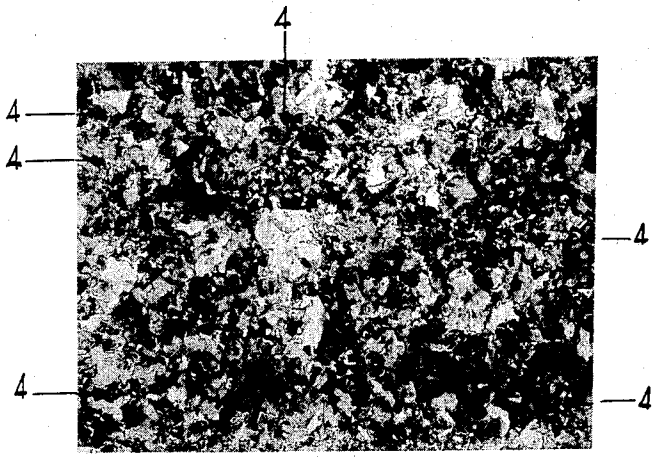


Fig. 2

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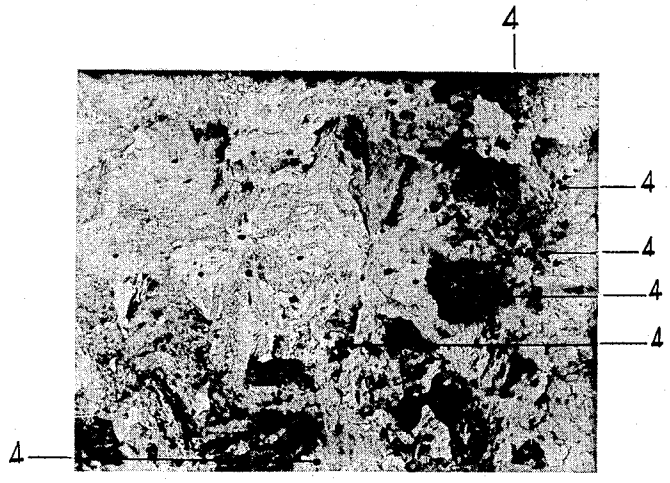


Fig. 3

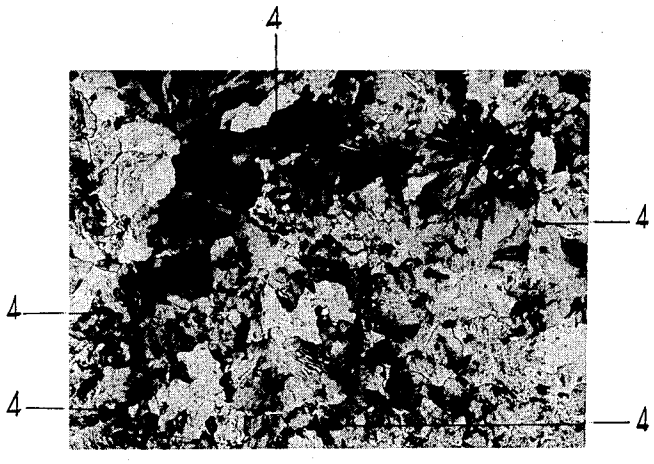


Fig. 4

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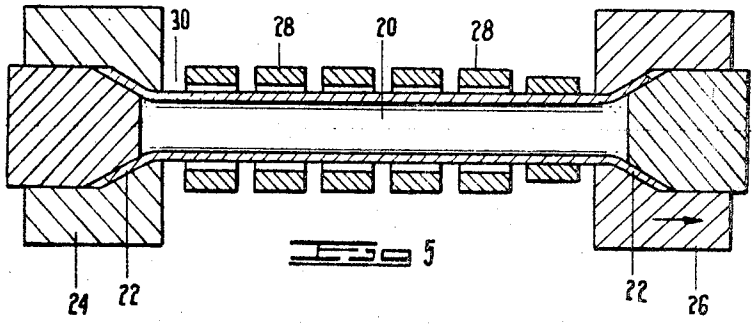


Fig 5

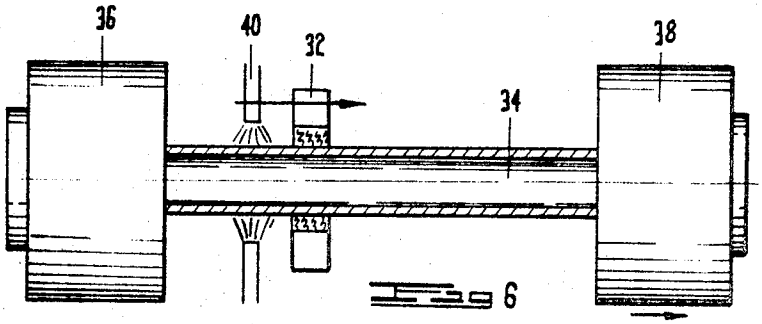


Fig 6

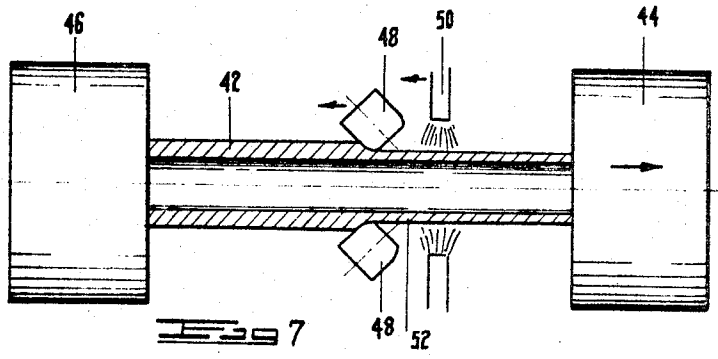


Fig 7

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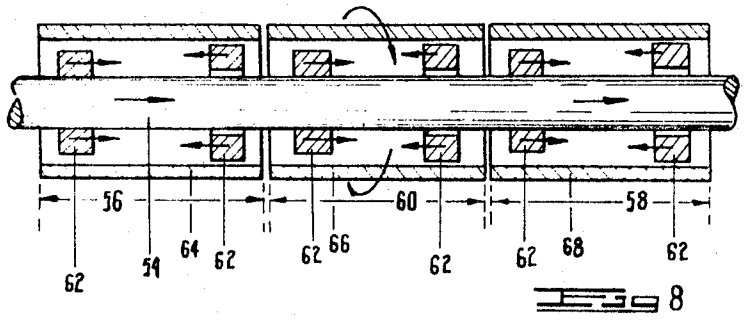


Fig 8

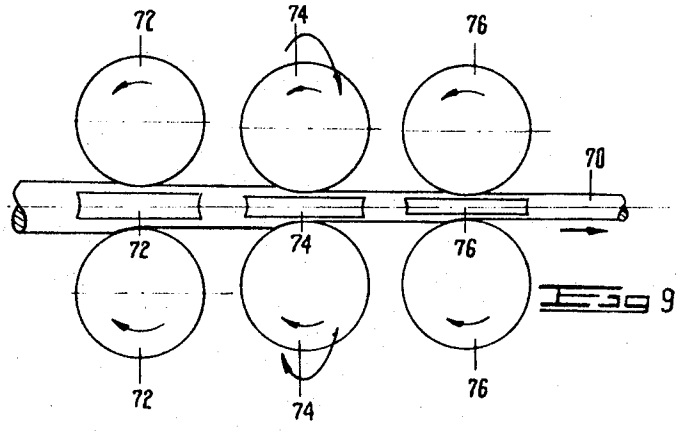


Fig 9

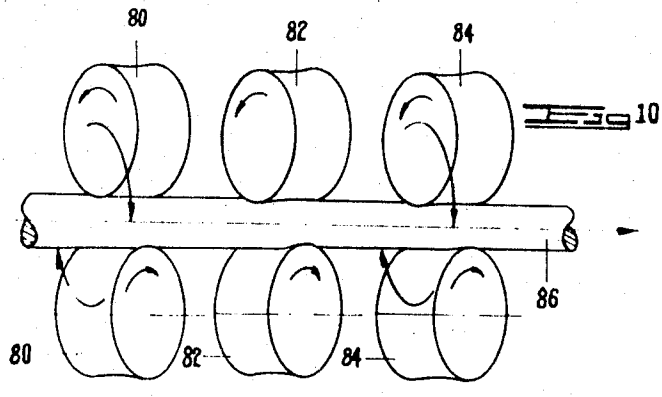


Fig 10

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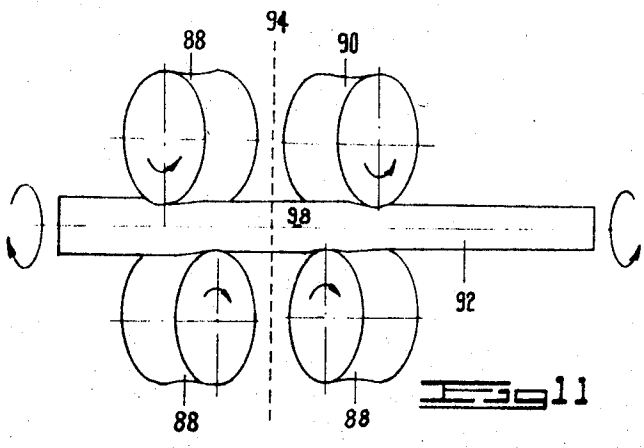


Fig 11

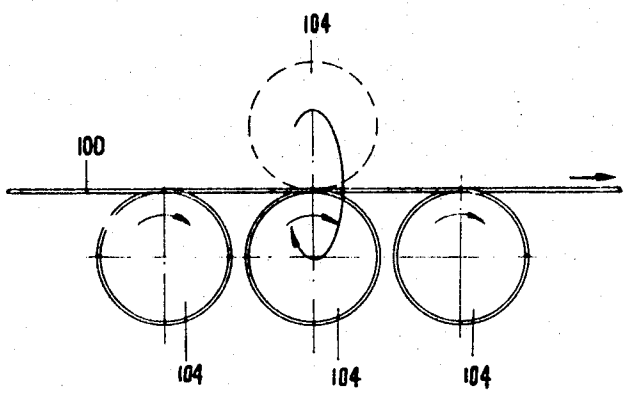


Fig 12

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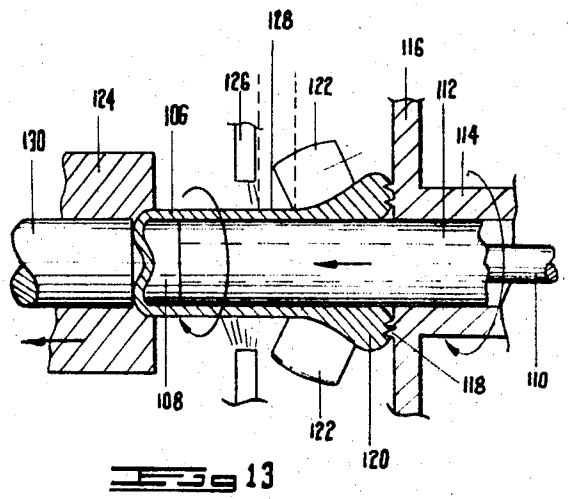


Fig 13

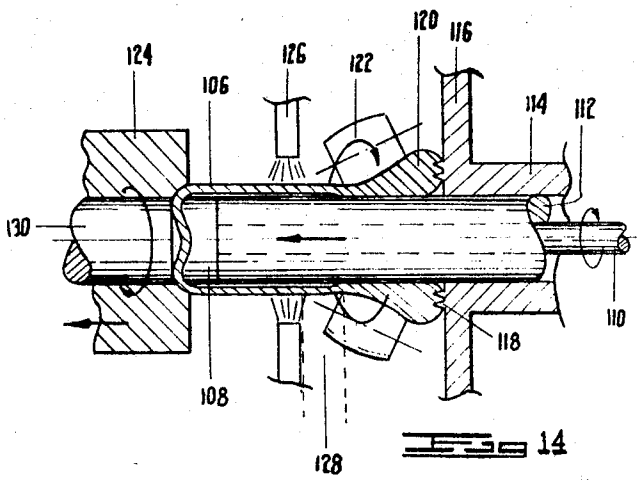


Fig 14

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Patented Sept. 16, 1969

3,466,916

WORKING OF PLASTICALLY DEFORMABLE MATERIALS

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Claims priority, application Republic of South Africa, May 5, 1966, 66/2,612
Int. Cl. B21d 11/14, 31/00
U.S. Cl. 72—299 17 Claims

ABSTRACT OF THE DISCLOSURE

Lengths of plastically deformable material having fibrous inclusions of foreign matter are treated to destroy the "grain" of the material, by successively isolating zones along the length and wringing the zone to break up the fibres into randomly oriented fragments.

Many materials exhibits a fibrous structure, corresponding to the direction in which force has been applied to the material during its manufacture. For instance, a steel bar or rod that has been rolled or extruded has a fibrous structure in the longitudinal direction. The fibres are caused by impurities, such as slag or oxide inclusions. During fabrication, the inclusions are stretched out to form the fibres, which are a source of weakness. Thus, if the fibres are present at the surface of an article, they can initiate flaking or pitting.

Ideally, materials such as steel should have no fibrous content, but unfortunately it is impossible completely to eliminate the impurities that cause them.

The object of the present invention is to provide a method of minimising the deleterious effects of fibrous inclusions in plastically deformable material, and apparatus to carry out the method.

According to the invention, a billet (which is meant to include a rod, bar or tube of the material) is gripped at two spaced points, while the material is hot enough to be plastically deformable easily, and torque is applied to the zone between the gripped points so to wring or twist the material composing the zone as to cause the fibres to fragment.

The effect of the wringing action to which the material is subjected is to break up the fibres into short lengths which are randomly oriented, as a consequence of which the strength of the material is greatly increased.

Torque may be applied in one direction only, but it is often desirable to apply a reverse torque, further to fragment the fibrous particles left by the first wringing operation.

The invention includes also various devices for applying the torque, which will be described later in relation to the accompanying drawings, wherein:

FIGURE 1 is a copy of a photomicrograph of a longitudinal section of a typical rolled steel bar, to a magnification of 144;

FIGURE 2 is a copy of a photomicrograph of a longitudinal section of the bar after it was treated by the method of the invention;

FIGURE 3 is a photomicrograph of a cross-section of the bar before treatment;

FIGURE 4 is a photomicrograph of a cross-section of the bar after treatment;

FIGURE 5 is a semidiagrammatic section through the operative part of one form of apparatus for carrying out the method of the invention;

FIGURE 6 is a semidiagrammatic section through a second form of apparatus;

FIGURE 7 is a semidiagrammatic section through a third form of apparatus;

FIGURE 8 is a semidiagrammatic section through a fourth form of apparatus;

FIGURE 9 is a semidiagrammatic section through a fifth form of apparatus;

FIGURE 10 is a semidiagrammatic section through a sixth form of apparatus;

FIGURE 11 is a semidiagrammatic section through a seventh form of apparatus;

FIGURE 12 is a semidiagrammatic view through an eighth form of apparatus, particularly applicable to wire billets;

FIGURE 13 is a semidiagrammatic section through a ninth form of apparatus, particularly applicable to billets drawn in the form of cylinders; and

FIGURE 14 is a semidigrammatic section through a tenth form of apparatus also particularly applicable to billets drawn in the form of cylinders.

The results which are produced by treatment of material in accordance with the method of the invention are shown in the photomicrographs of FIGURES 1 to 4. It will be observed in FIGURE 1 that rolling of the bar has drawn impurities included in the steel into fibres 2 running longitudinally. In FIGURE 3, a number of fibres 2 is seen in cross-section. It is obvious that, for components which have to perform arduous duties, such as bearing races where the weakness of the component is across the path of the rolling elements and localised stresses built up act on this weakness and all too often cause premature breakdown, the presence of the fibrous inclusions is highly disadvantageous.

In FIGURE 2, it will be seen that the wringing applied to the bar according to the method of the invention has caused complete fragmentation of the fibres 2, producing a number of spots 4 of impurity which, as is seen in FIGURE 2 and in the cross-section shown in FIGURE 4, are nondirectional and randomly dispersed through the body of the material. Clearly, such a fibreless structure is much better able to withstand damage than the fibrous structure of FIGURES 1 and 3.

Insofar as the extent to which the material is wrung is concerned, it is impossible to lay down a formula which is generally applicable to all materials. However, it can be said that the material must be heated sufficiently to render it plastically deformable. The heating may be overall, but is preferably applied progressively along the length of the workpiece, as will be shown when the apparatus suitable to carry out the method is discussed. It can further be said that the wringing must go well beyond that to which elongated steel articles like twist drills and reinforcing bars for concrete are twisted. In the prior art, such twisting has not, to the applicant's knowledge extended beyond the point where the fibrous inclusions are deformed to spiral shape: no significant rupture occurs of the fibres, which remain fibres in the treated steel.

As an example of the method of the invention, the bar which was used for the photomicrographs of FIGURES 1 and 2, had the following characteristics:

Rolled steel, carbon content 0.5 to 0.6 percent; moderate slag inclusions; length 18 inches and diameter (hexagonal) ⅞ inch. The samples from which the photomicrographs of FIGURES 1 and 3 were taken were cut from an end of the bar.

To treat the bar, it was mounted in a lathe with one end clamped in the chuck and the other in the tailstock. The bar was heated medially, in a zone of about 1 inch length, to a temperature of about 800° C. (i.e., about 50° C. above the upper critical temperature of the steel). The machine was then started and the chuck was rotated

through about 150 revolutions while the tailstock was clamped against rotation. Twisting of the bar took place only in the heated zone, which bulged diametrically and contracted axially during wringing. The samples photomicrographed in FIGURES 2 and 4 were cut from the central portion of the twisted zone after the bar had cooled.

Various embodiments of apparatus suitable to carry out the method of the invention are illustrated in FIGURE 5 et seq. These drawings are semidiagrammatic and illustrate only those components involved in the wringing action, the remaining structure being well known in the art.

In FIGURE 5, a billet or workpiece in the form of a tube **20** with flared ends **22, 22**, is clamped at these ends in a chuck **24** mounted for rotation and a fixed chuck **26**. Along the length of the tube are stationed a series of clamps **28** which may be operated manually, or preferably mechanically. The clamps **28** are initially all in operation to grip the tube, and hold it against rotation. The tube is preheated before being chucked to a temperature at which plastic deformation takes place easily, and after installation the chuck **24** is caused to rotate as shown by the arrow. Initially, wringing of the tube takes place only in the zone **30** between the chuck **24** and the nearest clamp. Progressively, the clamps **28** are released, from left to right in the figure, so that the zones progressively isolated are wrung. This operation is preferably accompanied by a tensioning operation, indicated by the arrow above the chuck **26**, which acts to minimise the tendency of the tube **20** to bulge. In the figure, the treatment has proceeded to the stage where only the clamp nearest the chuck **26** remains in gripping engagement on the tube.

The form of apparatus illustrated in FIGURE 5 would be equally suitable for treating solid bars.

It will be appreciated, of course, that isolation in these instances consists of wringing a zone and then passing on to the next succeeding zone. The wrung zone offers greater resistance to wringing than the next, unwrung zone, so that it is the latter on which the wringing action is effective. If the zone or zones already wrung should be further twisted, it is of no consequence, but preferably they are reclamped to ensure an orderly progression of the process.

In FIGURE 6 the isolating means is a heating means **32** such as an RF coil which moves along the length of the billet, a tube **34** clamped at its ends in chucks **36** and **38**. Trailing the heater **32** is a cooling means **40** such as a water spray, that confines the heating effect, so that the zone being heated is, say, 50° to 100° C. above the general temperature to which the billet has been preheated before being installed in the machine. The inreased plasticity of the zone being heated is sufficient to ensure that torque applied to the chucked ends of the tube **34**, by rotation of the chuck **36**, should cause twisting to be substantially confined to that zone.

In FIGURE 7, a chucked workpiece in the form of a tube **42** has one end rotated by a chuck **44** and the other held stationary in a chuck **46**. A set of skewed rollers **48**, arranged radially around the workpiece and drive about their axes (by means not illustrated) is caused to traverse the workpiece **42** (for instance, by advancing a cage within which the roller may be mounted) in the direction of the arrow. "Skewed" is used in the sense that the rollers have their axes oblique to the axis of the workpiece. A water spray **50** or other cooling means trails the rollers as they advance. The action of the rollers on the tube **42** reduces the thickness of the material of the tube and yields, in the region **52** between the rollers and the water spray **50**, an isolated zone in which there is less resistance to wringing than in the unreduced portion of the tube and the portion, between the water spray **50** and the chuck **44**, in which wringing has already taken place. The result is that wringing is substantially confined to the zone **52**.

Thus far, the embodiments have related to batch production. Some consideration will now be given to continuous production.

In one type of apparatus according to the invention, a workpiece of considerable length is advanced past a wringing head where units of its length are progressively treated. The advance may be intermittent, in which case each time the motion is arrested, the zone of the workpiece at the wringing head is isolated and is twisted. The isolation may consist of mechanically gripping the workpiece to isolate the zone, or of heating the zone above the temperature of adjoining zones.

Alternatively, the advance may be continuous, in which case the isolating means may also be movable, to keep abreast of the zone being isolated. For instance, if the means is mechanical, the grippers may oscillate, to grip during the advancing movement and to release the workpiece during the retreating movement. The operation may be likened, in this case, to a team of two men pulling in a rope hand over hand, in unison. The portion of the rope between the pair of hands at any time grasping the rope is isolated from the remainder of the rope, while the other hands move rearwardly before resuming their grip on the rope.

Whether the advance of the workpiece is continuous or intermittent, each isolated zone is twisted. Preferably this is done always in one direction and at the middle of the zone. It follows that the portions of the zone to the right and the left of mid-point are twisted oppositely. If, then, the advance of the workpiece is so calculated that it is one half the length of the zone (if the movement is intermittent) or (if it is continuous) that the twisting means is operative twice for each unit length, then the trailing half of each zone becomes the leading half of the next zone. Thus, each half-zone is twisted twice, but in different directions. The dissociation of the fibres is thus made more thorough than if only a single twist is done.

Several methods of achieving this "double-twisting" effect are illustrated in FIGURE 8 et seq.

In FIGURE 8, a preheated bar **54** is advanced continuously through the machine in the direction indicated by the arrow. The length of bar within the machine is divided into three zones, the outer ones **56**, and **58** being zones in which the bar is gripped and held against axial rotation, and the middle zone **60** being the zone in which the bar is twisted. Two grippers **62** operate in each zone, reciprocating along the bar, gripping it as they travel in one direction and being released from it as they travel in the opposite direction. The grippers in all the zones are similar. Each comprises two or more segments which partially surround the bar. The segments are splined and reciprocate in complementally splined sleeve holders **64, 66** and **68** which surround the bar and extend along the lengths of the respective zones **56, 60** and **58**. The holders **64** and **68**, in the end zones **56** and **58**, are clamped against rotation. The central holder **66** is driven about the axis of the bar (by means not illustrated) in the direction indicated by the arrow. For gripping the bar, the segments of each gripper **62** are moved radially inwardly towards the bar by hydraulic, mechanical, or similar means (not illustrated). To release the bar, the gripper segments are withdrawn radially outwardly. For reciprocating movement, the grippers may be moved by cams, cranks or the like.

The action of the grippers is such that, while one gripper in each zone grips the bar, it simultaneously advances the bar through that zone. During this operation, the other gripper of the same zone is released and returns in the opposite direction to resume the position in which it grips the bar to advance it. Thus at all times the bar is gripped by one gripper in each zone and is advanced by it through the machine. In the middle zone **60**, the bar is constantly rotated by rotation of the holder **66**. A portion of the bar in that zone is twisted in one direction, and another portion is simultaneously twisted in the op-

posite direction, and the resultant deformation serves to fragment the fibres in the bar.

Similar results are achieved by the embodiment of FIGURE 9, where a bar **80** is advanced through three sets of rollers **72**, **74** and **76** in the direction of the arrow. The rollers of each set are identical, and rotate in planes parallel to the axis of the bar. The periphery of each roller is grooved to engage the surface of the bar. The sets of rollers **72** and **76** have fixed axes. The rollers of the set **74** orbit around the bar, being mounted in a cage (not illustrated) driven by external means. The rollers of the various sets may be driven about their axes to cause advance of the bar, or the bar may be pushed or pulled through the machine by external means. Orbiting of the set of rollers **74** isolates a zone between the rollers **72** and **76** within which the bar is twisted to break up the fibres. The twisting is again of the dual nature described above. The action of the rollers on the bar also serves to reduce its diameter as it advances.

In FIGURE 10, the same arrangement in essence is shown, but the pairs of parallel rollers are substituted by sets of skewed rollers **80**, **82** and **84**, the outer sets **80** and **84** idling and at the same time orbiting as shown by the arrows to permit advance of the bar **86** and to grip it against rotation, while the central set **82** is fixed against orbiting and therefore applied a twist to the bar **86**.

In FIGURE 11, two sets or pairs **88**, **90** of skewed rollers are provided which are fixed against orbiting and which are driven to impart motion to the bar **92** and at the same time to apply torque to it. The bar **92** is of fixed length, its ends free to turn in response to the action of the rollers. The material of the bar in the plane **94** midway between the sets of rollers is unwrung, and the half-zones **96**, **98** to each side of the plane **94** are wrung in opposite senses, so that all units of length of the bar are double-twisted during their passage past the wringing head. The bar to each side of the head rotates freely, as shown by the arrows.

In FIGURE 12, a flexible workpiece such as a length of wire **100** is advanced in the direction of the arrow by rotation of three capstans **102**, **104**, **105** around which the wire is wound, and the portions of the wire between the capstans is wrung by orbital movement of the middle capstan **104** about the line of advance of the wire, as shown by the arrow and dotted lines. The capstans **102**, **105** might, of course, be replaced by other members clamping the wire against rotation but permitting its axial advance.

The application of the method of the invention to the fabrication of closed-ended tubes or cylinders is illustrated in FIGURES 13 and 14. The cylinders **106** may, for instance, be the tanks of gas appliances, which are designed to hold high pressures and in which it is particularly desirable to ensure that a thickness of wall which is not so great as to make the appliance cumbersome and expensive, is not marred by flaws in the metal. In FIGURE 13, the billet from which the cylinder **106** starts is a slug, which is heated and indented by an end pad **108** shaped complementally to the shape required of the end of the cylinder. The pad **108** is attached to a plunger **110** which is fixed against rotation but is mounted to be extended as drawing of the cylinder **106** proceeds. The plunger **110** is surrounded by a sleeve **112** which is free to rotate on the plunger, the surface of the sleeve defining the inner surface of the cylinder. The sleeve in turn is surrounded for a portion of its length by a headpiece **114** having a flange **116** surfaced by protruding spikes **118** which are embedded in the billet **120** to prevent relative rotation. The headpiece **114** is driven about the plunger axis as indicated by the arrow. The billet is thinned to cylindrical shape by the action of skewed rollers **122** mounted around the periphery of the billet and defining with the sleeve **112** a throat through which material from the billet passes with rotation of the rollers **122**. The end of the cylinder **106** is mounted in a clamp **124** which is arranged to advance with advance of the plunger **110** but which is fixed against rotation. A pusher **130** is set in the clamp **124** to force the cylinder **106** out of the clamp when the operation has been completed. A cooling means **126** such as a water source is mounted around the cylinder **106** a short distance behind the rollers **122**. With rotation of the rollers **122** about their axes, and rotation of the headpiece **114**, together with advance of the plunger **110** and clamp **124**, wringing takes place in the zone **128** isolated between the rollers **122** and the cooling means **126**.

A related embodiment is shown in FIGURE 14, where the components have been numbered similarly to those in FIGURE 13. In FIGURE 14, the plunger **110** rotates as shown by the arrow, in addition to advancing to extend the cylinder **106**. The pad **108** is fixed to the plunger **110**. The plunger **110** and pad **108** rotate at the same speed as the clamp, otherwise there would be relative motion between the components **108**, **124** and **130**. The headpiece **114** is fixed against rotation, but the rollers orbit about the billet **120** as shown by the arrow. They themselves are not driven about their axes, but rotate because of the friction between themselves and the billet **120**. This arrangement has the advantage that, in the wringing zone **128** and for the remainder of the length of the formed cylinder, the internal diameter of the cylinder is somewhat greater than the diameter of the sleeve **112**, so that the sleeve is easily retractable when drawing of the cylinder ends. This bulging is a result of the passage of the material of the billet through the rollers.

I claim:

1. A process of treating a plastically deformable material having fibrous inclusions of another material, which consists in heating a length of the material sufficiently for the material to be easily plastically deformable, isolating a zone of the heated material, and applying torque to the isolated zone so to wring the material composing the zone as to cause the fibres to fragment.

2. The process of claim **1** in which torque is applied to the isolated zone in one direction, and the torque is then reversed to apply the wringing action in the opposite direction.

3. The process of claim **1** in which the material is an elongated formation and the zone is isolated by gripping the material at two spaced points.

4. The process of claim **3** in which a succession of zones, one after the other, is isolated along the length of the formation from the rest of the formation, and each zone is wrung in turn as it is isolated, and released after wringing.

5. The process of claim **4** in which the zones are successively isolated by applying heat to the zones in turn to decrease their resistance to wringing.

6. The process of claim **5** in which each heated zone is isolated from the remainder of the formation by cooling the zones to each side of the zone being heated.

7. The process of claim **1** in which isolation of the zone to be wrung is, at least in part, affected by reducing the cross-section of the material by rolling.

8. Apparatus for treating a plastically deformable elongated billet having fibrous inclusions of foreign material, comprising aligned chucks to hold the ends of the billet, driving means to rotate the chucks relatively to each other to apply torque to the billet, a series of clamps adapted to be spaced along the length of the billet and to prevent wringing of the billet in a zone held by the clamps, means to operate each clamp individually, and means biasing the chucks apart.

9. Apparatus for treating a heated plastically deformable elongated billet having fibrous inclusions of foreign material, comprising aligned chucks to hold the ends of the billet, driving means to rotate the chucks relatively to each other and so apply torque to the billet, a set of rollers mounted between the chucks around their common axis and adapted to encircle the billet, means to move the rollers relatively to the chucks along the common axis, thereby to reduce the cross-section of the billet; means spaced axially apart from the rollers to cool the billet

after reduction of its cross-section by the rollers; and means to draw the chucks apart.

10. Apparatus for treating a plastically deformable elongated billet having fibrous inclusions of foreign material, comprising three clamping members spaced apart along a path, each clamping member being adapted to hold a portion of the billet against rotation but to permit its axial advancement along the path; means to advance the billet continuously through the clamping members, and means to rotate the middle clamping member relatively to the other clamping members.

11. The apparatus of claim **10** in which at least one of the clamping members consists of a set of rollers mounted to engage the billet around its circumference.

12. The apparatus of claim **11** in which the rollers are mounted to rotate in planes parallel to the axis of the billet.

13. The apparatus of claim **11** in which the rollers are skewed.

14. The apparatus of claim **10** in which at least one of the clamping members consists of a set of at least two releasable grippers arranged for reciprocating movement along adjacent portions of the path; means to move the grippers in reciprocating motion out of phase with each other; and means to release the grippers when they cease to move in the direction of advance of the billet and to engage them when they begin to move in that direction.

15. The apparatus of claim **10** in which the middle clamping member consists of a capstan about which the billet is adapted to be wound, the capstan being mounted for rotation about its own axis and also for orbiting motion; and including means to move the capstan in rotary and orbital motion.

16. Apparatus for treating a plastically deformable elongated billet having fibrous inclusions of foreign material, comprising two sets of rollers, spaced apart, each set

comprising at least two skewed rollers adapted to engage the billet and being mounted for rotation about fixed axes; and including driving means so to rotate the rollers of each set as to cause rotation of the billet between those rollers; rotation of the billet between one set of rollers being in opposite direction to rotation of the billet between the second set of rollers.

17. Apparatus for treating a heated plastically deformable tubular billet having fibrous inclusions of foreign material, the billet having a closed end; comprising clamping means to grip and rotate the ends of the billet relatively to each other; means to support the inner surface of the billet; a set of rollers mounted around the billet between its ends to define, with the support for the inner surface, a throat narrower than the wall thickness of the open end of the billet; a plunger extending into the billet; cooling means for the billet stationed between the closed end and the rollers and defining, in the space between itself and the rollers, a wringing zone; means to cause orbital motion of the rollers relatively to the billet; and means to advance the plunger and clamp for the closed end of the billet.

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