United States Patent Office 2,716,080
Patented Aug. 23, 1955

2,716,080

PROCESS FOR INCREASING THE STRENGTH OF STEEL

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No Drawing. Application October 9, 1951, Serial No. 250,567

Claims priority, application Germany October 13, 1950

9 Claims. (Cl. 148—12)

The invention relates to a process for increasing the strength of unalloyed or alloyed bar steels, tubes or the like, and the essential feature consists in that commercial sectional steel is mechanically compressed in the cold by cold-hammering, pressing or transverse rolling in one or more passes or transits. This cold compression produces, even with a single transit, an increase in strength of about 20–25% with corresponding reduction of the elongation and increase of the hardness, for example with commercial reinforcing iron for concrete, and with a number of transits, an increase in the strength of 100% and more. The coarse grained structure of the iron is converted over its entire cross-section into a fine-grained structure.

With advantage, commercial rolled bar steel is first of all cold-drawn, then cold-compressed by hammering, pressing or transverse rolling and then annealed. By means of the initial cold drawing, there takes place a surface hardening which, with the following cold compression by hammering, pressing or transverse rolling having a greater depth action, has a corresponding effect, and by the subsequent annealing at about 500 to 700° C., the internal tensions are eliminated while maintaining the compression. After the annealing and cooling, the outer skin is not brittle as with drawn steels, and such a bar can be bent or otherwise deformed in the cold with less danger of breaking for example by rolling in screwthreads, splines or grooves, whereby a surface-hardening is again effected.

Steel drawn in the usual manner is expediently annealed before the cold compression in order initially to eliminate surface tensions, the size of which is not known, and which are then reproduced in a known value by the drawing and cold compression.

A particularly advantageous arrangement is provided when the main treatment consisting of cold-drawing, cold compression with deep mechanical action and subsequent annealing, is repeatedly carried out, for example two to three times in succession. In this way, the mechanical cold compression always proceeds according to the grain of the cross-section with satisfactory grain formation, so that the total strength is always increased, for example by about 10 kg./mm.^{2} with each step.

A further advantageous arrangement is obtained when the main treatment is repeated until no further increase in strength is produced. The cold compression has then progressed as far as the core.

A further advantageous arrangement is obtained when the steel bar is drawn in the cold after the annealing operation of the last main treatment. By this means, there is again obtained a particular compression and thus increase in strength and smoothing of the outer layer.

In comparison with the original rolled steel, the strength can be increased by this treatment to about twice the original strength.

A further advantageous arrangement is obtained when using steel bars which harden under heat if the steel is hardened by heat treatment (heating and cooling) after

the last main treatment and any final drawing which takes place.

An advantageous arrangement is obtained if the last cold compression is carried out several times (two or three times) in succession with the same cheek formation. In the first transit, there is then obtained a reduction in diameter of for example 5–10% (with a diameter of about 10 mm.), of about 1% in the second transit and about 0.02% in the third transit. After the first transit, the bar steel is still rather irregular in diameter, whereas after the second and third transits, the steel is very regular and round bar steels are thus completely smooth and round so that they do not have to be finally drawn. In this way moreover, a surface hardening unfavourable for bending is avoided, and the bar steels also do not require to be re-annealed in many cases, so that they retain their full strength.

The process is also capable of being used for the strengthening of tubes if, during the cold compression steps, a mandrel or steel rod is introduced with clearance into the tube.

Normally drawn tubing is advantageously first of all annealed and then cold compressed and thereafter drawn externally and internally or subjected to a burnishing. By means of the annealing operation, the uniform but not deep surface hardening is removed and replaced by a cold compression operating to a greater depth and produced by the subsequent hammering, pressing or transverse rolling. In this way, the inner wall of the tube is more strongly compressed than the outer wall, and there are formed annular compressive stresses in the direction of the inner tube wall, said stresses being counter-balanced by annular tensile stresses of the outer tube wall. If such tubes are stressed by internal liquid or gas pressure, the internal annular compressive stresses have first to be overcome before tensile stresses can be formed in the inner wall. Since the tubes are expanded more strongly on the inside than on the outside by such internal pressures, the final annular stresses which are produced are made uniform over the entire cross-section of the tube wall. Such tubes therefore do not burst so easily from the inside as ordinary tubes.

The treatment consisting of annealing, cold compression, and drawing or burnishing can be repeated several times and if desired until no further increase in strength is produced.

With repeated treatments, the tube can also be drawn only from the outside and the treatment repeated until the tube is shaped approximately or wholly like a solid steel rod. By this means, the material is substantially stretched and strengthened in the longitudinal direction with a satisfactory formation of longitudinal grains. Since the material in this case is initially also made uniform from the inside by cold compression and drawing pores and blow-holes are positively avoided. Such tubes or rods may be employed with particular satisfaction as draw bars.

After the final treatment, such tubes or rods are expediently annealed, this preferably taking place only in the outer regions of the cross-section so that they are adapted to be bent easily and are particularly suitable for use as reinforcing irons for concrete or the like.

According to the invention, for example, commercial drawn round bar steel, or such steel which has not been drawn, is simultaneously hammered or pressed in hammering or pressing machines by means of half-round or quarter-round shaping hammers or pressing cheeks from two or four sides, and this cold compression, if necessary with always somewhat narrower hammering or pressing cheeks, is repeated one or several times. The last hammering or pressing is advantageously repeated in two to three transits with the same hammering or pressing cheeks.

In this way the bar steel becomes very uniform, smooth and round, and its strength increases even during the second and third transit through the same hammering or pressing cheecks. The coarse-grained structure of the material thus becomes fine-grained and very dense. If the bar steel is to be bent with small radii of curvature, it can also be annealed again, particularly in its outer layer. A final drawing is not necessary.

If tubes are compressed and strengthened, then a fitted mandrel is placed with some clearance in the tube for each hammering, pressing or rolling operation. The last two to three operations are in this case also carried out with the same shaping tools.

According to another embodiment, commercial round bar steel, if it is drawn, is initially annealed and cooled, or, if it is only rolled, it is subjected directly to a main treatment in the following manner. First of all, the steel bar or rod is drawn in the cold and then simultaneously hammered or pressed in hammering machines by means of half round shaping hammers from two sides, or intermittently rolled transversely between two rollers and a steel straight edge provided with lubrication and arranged in a roller gap, the rod or bar sliding on the steel straight edge being turned about its longitudinal axis by the rollers. Thereafter the rod or bar is annealed at 500–700° C. and then cooled. This main treatment is expediently carried out two to three times or even more, until no further increase in strength is apparent after the last main treatment. Due to the main treatments, the compression towards the core of the rod is progressively increased and thus the total strength is also intermittently increased so that finally the total strength is about twice as great as at the commencement of the first main treatment. This main treatment also produces a good grain formation, and the internal tensions are removed by each annealing operation so that the fibres do not crack during the subsequent cold compression. In this final condition, the outer layer is comparatively soft, that is to say it is not brittle, so that the rod can be bent to form reinforcing irons for concrete or the like without danger of breaking, or can be provided with rolled or impressed threads, splines, grooves or the like.

If it is desired to have a smooth outer surface and accurate dimensions, the rod can be again cold drawn. By this means is obtained a further increase in the total strength by about 10 to 20 kg./mm.^{2}.

The strength of normal unalloyed rolled steels can in this way be increased from 40–60 kg./mm.^{2} to 80 and to more than 100 kg./mm.^{2}.

If the starting material is a hardenable steel, the steel bar or rod can be further hardened by any available heat treatment after the last main treatment and if necessary after the final cold drawing. In this way, the strength can be still further increased by 10–20 kg./mm.^{2}.

The invention can be employed not only on round rods, but also on square, hexagonal or other polygonal rods. In this case, especially in the last main treatment, no transverse rolling is employed, but a hammering or pressing by means of shaped tools.

The annealing of the last main treatment and the following cold drawing can be dispensed with for many purposes of use.

The invention can also be used on other metals, for example brass or bronze.

Tubing drawn in the normal manner is first of all annealed, for example at about 500–700° C. and then, after insertion of a mandrel or steel rod fitting therein with clearance, is uniformly hammered or pressed from 2 to 6 sides in the cold state in hammering machines by means of shaping hammers adapted to the external shape of the tube, whereby the tube is slowly displaced through the machine or press and the mandrel is retained. The tube may instead also be rolled intermittently in the transverse direction between two rollers, said tube sliding on a steel straight edge arranged in the gap between the rollers as it is rotated about this longitudinal axis, the said mandrel if desired rotating with the tube but being held in the longitudinal direction. Thereafter the tube is cold drawn from inside and outside over a mandrel.

If desired, the annealing, cold compressing and drawing is repeated once to three times until the desired strength or hardness and density is obtained, which increases step-by-step with each treatment up to a certain value.

By the cold compression, internal annular compressive stresses are produced which are counterbalanced by external tensile stresses. Such tubes are particularly resistant to internal liquid or gas pressures.

In the repeated treatments, the mandrel in the cold compression and drawing can be omitted and the tube finally cold compressed into a solid rod which then has a very good longitudinal grain structure and is free from pores and blow holes. Such tubes with a very narrow internal passage and thick walling, or solid tubes, are then expediently annealed again, particularly on the outer surface, for example, by heat radiation, so that they are soft on the outside and are thus pliable. Such tubes or rods can be used particularly satisfactorily as concrete reinforcing irons.

Both the tubes and solid rods produced according to the process are also suitable for other purposes, such as for example, shafts or other structural parts of high grade machines and the like.

Instead of the drawing, it is also possible to carry out a burnishing by means of shaping tools in presses.

The strength of unalloyed drawn tubes is capable of being increased to about double the original strength by the process according to the invention.

By hammering, it is also possible to produce angular compressed thickwalled tubes from round drawn tubes.

The process can be used not only on steel tubes, but also on tubes of other metals, for example brass or bronze.

I claim:

1. A process of increasing the strength of steel, comprising the steps of annealing said steel, cold-drawing said annealed steel, thereby causing hardening of the surface area of the same; cold-hammering the thus cold-drawn steel in subsequent annular sections distributed over the surface of the same in at least one transit thereof so as to cause deep hardening of said steel, thereby causing hardening of the same throughout the thickness thereof; and alternately repeating said cold-drawing and cold-hammering until the strength of the steel is increased to a predetermined degree.

2. A process according to claim 1 in which said steel is annealed at a temperature of about 500–700° C. before and after each of said cold-working steps.

3. A process according to claim 1 wherein the final step is cold-drawing of said steel which is followed by annealing of said cold-drawn steel at a temperature of about 500–700° C.

4. A process according to claim 1 wherein said steel is annealed at a temperature of about 700° C. after the final cold-working step and said annealed steel is quenched.

5. A process according to claim 1 wherein said cold-hammering is accomplished by means of cheeks fitted to the cross-section of said steel.

6. A process according to claim 1 wherein said steel is in the form of a tube and wherein a mandrel fitting with clearance is introduced into said tube and said tube is advanced over said mandrel during the cold-hammering.

7. A process according to claim 1 wherein said steel is in the form of a tube and wherein said tube is annealed after said cold-drawing and then cold-hammered.

8. A process according to claim 7 wherein said tube after said cold-hammering is drawn and burnished internally and externally.

9. A process according to claim 1 wherein said steel

is in the form of a tube, said tube is cold-drawn only from the outside thereof, and said cold-hammering and cold-drawing is repeated until said tube is substantially changed to a solid steel bar.

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