

Dec. 10, 1957

H. HOFF ET AL.

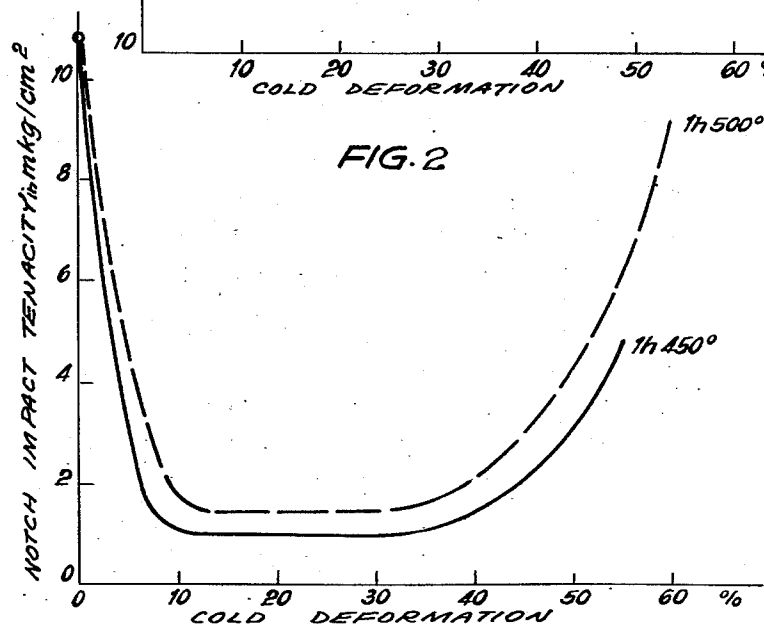
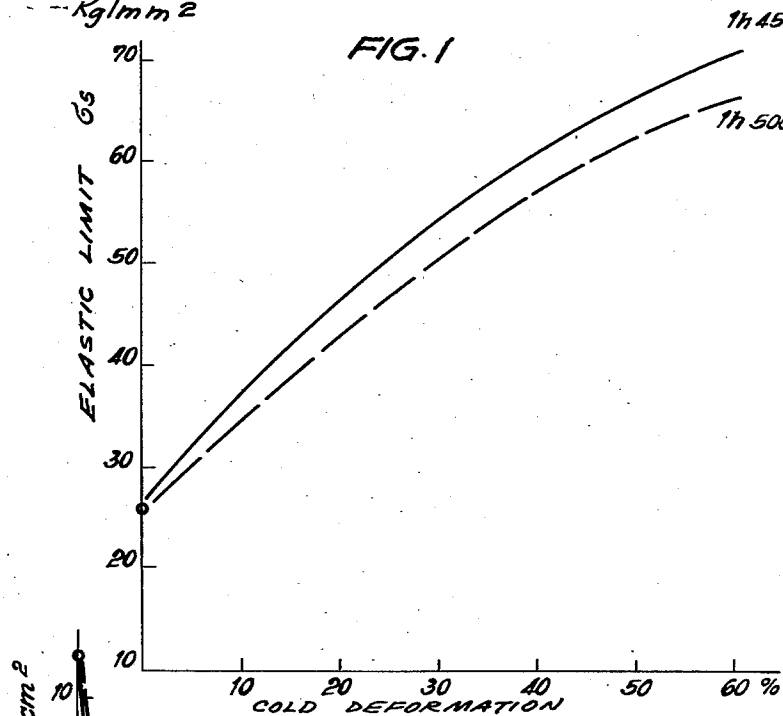
2,816,052

METHOD OF MANUFACTURING RIBBED STEEL RODS

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3 Sheets-Sheet 1

Kg/mm^2



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FIG. 3

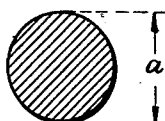


FIG. 4



FIG. 5

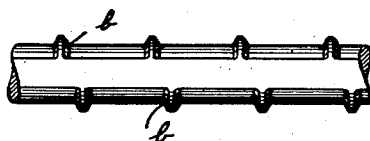


FIG. 6

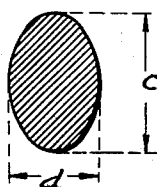


FIG. 7

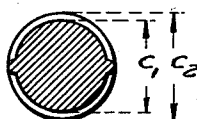
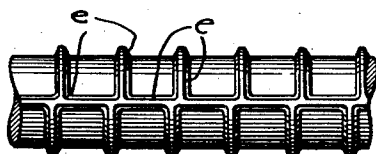


FIG. 8



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FIG. 9

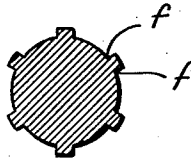
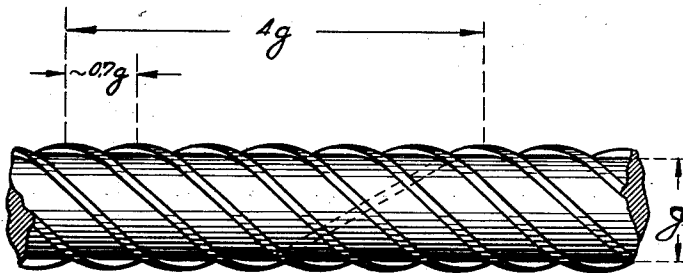


FIG. 10



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METHOD OF MANUFACTURING RIBBED
STEEL RODS

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Application November 8, 1954, Serial No. 467,602
Claims priority, application Germany November 7, 1953

14 Claims. (Cl. 148—12)

The present invention relates to a method of manufac-
turing ribbed steel rods, and more particularly to a meth-
od of manufacturing ribbed steel rods used for reinforcing
of concrete.

It is known that the elastic limit or yield point and
the strength of steel can be increased by cold deforma-
tion, and that the breaking elongation, which is consid-
erably reduced by cold deformation, can be improved by
subsequent tempering without causing considerable re-
duction in the elastic limit or strength of the steel due
to the tempering. However, it has been found that ob-
jects made in accordance with this process, and especially
objects made of Thomas steel, show brittleness in spite
of improved elongation quality wherever sharp notches
or indentations cause tension peaks under conditions of
stress.

For instance, concrete reinforcing ribbed steel rods
of Thomas steel, manufactured as described above and
belonging to group III^b and IV^b according to the German
standard DIN 1045 and having the following properties:

Special Concrete Reinforcing Steel-Type	Diam- eter, mm.	Tension Test			Bending Test	
		σ_s , kg./ mm. ²	σ_B , kg./ mm. ²	σ_{10} , Per- cent	Man- drel Diam- eter, g.	Bend- ing Angle, degrees
III ^b -----g--	≤ 18	≥ 42	≥ 50	≥ 8	3.5	180
IV ^b -----g--	≤ 26	≥ 40	≥ 50	≥ 8	3.5	180

are not usable, because breaks due to brittleness may
already occur during bending and positioning of the rein-
forcing rods at the building location. Hot-rolled Thomas
rib steel while possessing greater strength also does not
have sufficient tenacity.

It is also known to use steel rods formed with two
longitudinal ribs or with two longitudinal ribs and in-
terposed transversal or oblique ribs and to cold-twist these
rods for use as concrete reinforcements. These twisted
rods are preferably made with a pitch of 10-12 times
the rod diameter, especially when Thomas steel is used.
Increased twisting, especially reducing the pitch below 8
times the diameter of the rod causes the breaking tension
to fall below permissible limits. Making of highly twisted
reinforcement rods and tempering the same has not been
practical, since it was not known that by doing so con-
siderable improvements could be achieved not only in
regard to the values of the breaking tension but also in
regard to the ductility of the rod.

It is an object of the present invention to provide a
method for the manufacture of ribbed steel rods which
overcomes all of the above-mentioned disadvantages.

It is another object of the present invention to provide
a method for the manufacture of ribbed steel rods which
have great ductility, high breaking elongation and are
less apt to develop cracks and fissures under the strains

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and stresses connected with their use as concrete rein-
forcements.

It is still another object of the present invention to
provide a method for the manufacture of highly twisted
ribbed steel rods which have high breaking tension and
do not show a tendency towards developing cracks and
fissures.

It is a further object of the present invention to pro-
vide a method for the manufacture of ribbed steel rods
for reinforcing concrete which in addition to the afore-
mentioned advantages have a high degree of notch impact
tenacity.

Other objects and advantages of the present invention
will be apparent from a further reading of the specifica-
tion.

With the above objects in view the present invention
mainly consists in a method of manufacturing ribbed
steel rods for reinforcing concrete comprising the steps
of cold-rolling a steel rod and deforming the same so as
to reduce its dimensions in one cross-sectional direction
by at least 30%, thereafter tempering the cold-rolled de-
formed steel rod at a temperature ranging between 450°
and 600° Centigrade for at least 15 minutes, and form-
ing ribs on the steel rod not less than 15 minutes before
termination of the tempering whereby the cold-rolled
deformed steel rod with the ribs thereon is tempered for
at least 15 minutes at the indicated temperature.

More particularly the method of the present invention
comprises the steps of cold rolling a steel rod having
an oblong cross section and deforming the same so as to
reduce its dimensions in one cross sectional direction by
at least 30% and to form a circular cross section; form-
ing straight longitudinal ribs on the steel rod equally
spaced from each other in circumferential direction, twist-
ing the so-formed rod so that each of the straight longi-
tudinal ribs is deformed into a helical rib, the distance
of the thus-formed helical ribs from each other being
equal to about 0.7 time the diameter of the deformed steel
rod and the pitch of the helical ribs being less than 6
times the diameter of the deformed steel rod, and there-
after tempering the steel rod at a temperature ranging
between 450° and 600° centigrade for at least 15 minutes.

According to the present invention the cold rolling
of steel rods is performed in such a way as to achieve
a decrease in the thicknesses of the rods equal to a de-
formation of at least 30% in the area between the ribs.
The tempering is performed at a temperature of between
450° and 600° C. for a sufficiently long period of time
so as to obtain increasing values for notch impact re-
sistance without appreciable decrease in the elastic limit
and strength of the steel rod.

The fillet-shaped area connecting the ribs with the steel
rod is in accordance with the present invention exposed
to even greater deformation, preferably ranging between
30 and 60%. Due to the increased deformation recryst-
allization takes place in this area during tempering, and
consequently stresses which otherwise might cause forma-
tion of cracks are relieved. This is achieved by forming
the ribs in such a way that the cross-section of the
area connecting the ribs with the steel rod forms an arc
of very small radius.

The ribs may be rolled onto the rod either cold or
at tempering temperatures.

The rod prior to the cold-rolling process of the present
invention may have various cross-sections such as for
instance oblong, rectangular or circular, and may have
been produced by a hot or cold rolling process. It is
then cold-rolled and deformed to the desired cross-section.
For instance, a rod of square cross-section is cold-rolled
into a rod of elongated rectangular cross-section or vice
versa; a rod of oval cross-section is cold-rolled into a

rod of circular cross-section, or a rod of circular cross-section is cold-rolled to a rod having a cross-section of oval shape, both having transversal ribs. The cross-section of the rod may be changed by cold-rolling in accordance with the present invention in any desired way, provided that a deformation of at least 30% takes place during the cold-rolling. For instance, the rod can be cold-rolled along two axes perpendicular to each other in order to achieve deformation of at least 30% and to form at the same time ribs on the surface of the rod.

It has now been found that the tenacity or ductility of cold-rolled and tempered steel, especially Thomas steel, can only then be improved without considerable loss of strength and reduction of the elastic limit or yield point, when the cold deformation exceeds a certain minimum value and when the tempering takes place within a definite range of temperature. For the cold-rolling, depending upon quality and condition of the material, a reduction in thickness of at least 30% is required. This minimum reduction value is not determined by the shape of the steel rod or by the required values for the yield point or tensile strength but by the tenacity and ductility required of high grade concrete reinforcing rods.

In accordance with the present invention, the tempering, following deformation of the rod in excess of the above stated minimum, has to be carried out within the temperature range of 450° to 600° centigrade, in order to achieve a considerable increase in tenacity and ductility concurrent with a high elastic limit and great strength of the steel rod.

Tempering at a temperature below 450° centigrade tends to improve only the elastic limit which has been reduced during cold deformation, however, it does not appreciably change the notch impact tenacity in stress areas such as the fillet or notch-like areas connecting the ribs with the main body of the rod.

On the other hand, if during tempering the temperature increases above a limit of from 580° to 600° centigrade, a decrease in strength occurs due to recrystallization taking place throughout the entire cross-section of the steel rod.

Above the lower limit of cold deformation and within the temperature range provided by the present invention, the notch impact tenacity increases with increasing deformation and higher tempering temperatures, whereby the elastic limit or yield point and the strength of the steel rod continue to increase with the increase in deformation causing reduction of the thickness of the rod in one direction. In order to achieve a high notch impact tenacity it is therefore advisable in accordance with the present invention to obtain the highest possible degree of cold deformation and to temper at high temperatures which, however, must not exceed the upper limit of between 580° and 600° centigrade.

The usual tempering time of between 2 and 5 minutes is not sufficient to achieve the desired increase in notch impact tenacity. In accordance with the present invention the tempering process has to extend over a period of from 15 to 90 minutes.

By working in accordance with the method of the present invention as above described, especially the notch impact tenacity of cold deformed soft Thomas steel is considerably improved. By applying for instance, a very high degree of cold deformation, corresponding to a reduction in thickness of about 60%, followed by suitable tempering, for instance of one hour at 500° centigrade, it is possible to approximately regain the notch impact tenacity of the hot-rolled initial material, while at the same time increasing the elastic limit to about 2.5 times its initial value.

The process of the present invention is especially suitable for the manufacture of ribbed concrete reinforcing rods belonging to groups IIIb and IVb of the German standards DIN 1045 which were described further above.

It is important in this case to achieve not only an in-

crease in the notch impact tenacity together with a high degree of cold deformation, but also in addition to reduce considerably the notch effect in the area connecting the ribs with the main body of the steel rod. This is done by recrystallization of the material in this area. In order to achieve this result it is necessary to increase the deformation in the area connecting the ribs with the main body of the steel rod to a considerably higher value than the deformation of the remainder of the cross-section of the steel rod; so that during tempering recrystallization and relieving of stress occurs only in this particular area, while the strength of the remainder of the steel rod remains substantially unchanged at the level attained by the cold deformation process. Due to the relieving of strain of the material in this area, a high capacity for deformation is obtained which is necessary for an effective reduction of the stress peaks. In this way it is possible to manufacture from soft Thomas steel, for instance, cross-ribbed concrete reinforcing rods which conform with the German standards according to DIN 1045 for concrete reinforcements of steel of the groups IIIb and IVb and which in comparison with concrete reinforcement rods made from Thomas steel in accordance with other methods show considerably better qualities in regard to tenacity and resistance against formation of cracks, while being of equal strength.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Fig. 1 is a graph showing the stretch limit of steel under tempering conditions in accordance with the present invention, in relation to the degree of cold deformation;

Fig. 2 is a graph showing the impact tenacity of steel under tempering conditions in accordance with the present invention, in relation to the degree of cold deformation;

Fig. 3 is a cross-sectional view of a cylindrical steel rod prior to deformation in accordance with the present invention;

Fig. 4 is a cross-sectional view of the steel rod shown in Fig. 3, after deformation;

Fig. 5 is a plan view of the steel rod shown in Fig. 4;

Fig. 6 is a cross-sectional view of an oval steel rod prior to deformation in accordance with the present invention;

Fig. 7 is a cross-sectional view of the steel rod shown in Fig. 6, after deformation;

Fig. 8 is a plan view of the steel rod shown in Fig. 7;

Fig. 9 is a cross-sectional view of a steel rod provided with longitudinal ribs in accordance with the present invention; and

Fig. 10 is a plan view of the steel rod shown in Fig. 9 after twisting of the same.

The relationship between the reduction of thickness and the elastic limit at tempering temperatures of 450° and 500° centigrade and at a tempering time of one hour is shown in Fig. 1, while Fig. 2 shows the change in the notch impact tenacity under deformation and tempering conditions identical with those of Fig. 1. The tempering time depends on the size of the cross-section of the steel rod.

As graphically illustrated in Figs. 1 and 2, the elastic limit increases with the increase in cold deformation, while the notch impact tenacity decreases upon application of a small degree of cold deformation and only starts to increase when the degree of cold deformation reaches values approaching 40%. Upon further increase in the cold deformation, up to between 50 and 60%, the notch impact tenacity shows a very high rate of increase.

Figs. 1 and 2 graphically illustrate why in accordance

with the present invention the area connecting the ribs with the main body of the rod has to be deformed to a higher degree than the other portions of the ribbed steel rod. As shown in these figures a sufficiently high value for the elastic limit is obtained when deformation exceeds 30%, while deformation between 40 and 60% in the critical area between the ribs and the rod is needed to obtain a satisfactory increase in the impact tenacity.

This is utilized in accordance with the present invention, in regard to twisted ribbed steel rods for concrete reinforcements, and done by twisting the ribbed rods to such an extent that the pitch of the helical ribs formed from originally longitudinal ribs by twisting of the steel rod, is below six times the maximum dimension of the cross-section of the rod, preferably between two and four times the maximum dimension. If for example a ribbed rod of circular cross-section having straight longitudinal ribs equally spaced from each other in circumferential direction is used, the twisting in accordance with the present invention is to be carried out to such an extent that the pitch of the helical ribs formed thereby is smaller than six times the diameter of said rod and preferably lies between two and four times that diameter. Twisting of the steel rod to the extent indicated above and subsequent tempering for a period of between 15 and 90 minutes, depending on the size of the cross-section of the ribbed rods, at a temperature of between 450 and 600° C. will cause the notch impact tenacity to increase again, without appreciable reduction of the high elastic limit and strength achieved by the cold twisting of the rod.

According to this process of the present invention an improvement in the mechanical characteristics of the steel rods is achieved and the desired values in respect to notch impact tenacity and elastic limit are reached.

Furthermore, a new and considerable advantage is achieved for having the helical ribs, formed from longitudinal ribs by twisting of the steel rod, arranged at such slope as to show a certain similarity with rods having transversal ribs. As it is known, transversal ribs on concrete reinforcing rods possess the extraordinary advantage of increasing the adherence of the concrete to the reinforcing rod. The steep helical ribs of conventionally twisted reinforcing rods provide a somewhat better adherence than smooth rib-less reinforcing rods. However, longitudinal forces acting on the embedded reinforcing rod create, in the case of steep helical ribs, a relatively large force component in the direction of the ribs and consequently the rod shows a certain tendency to separate from the concrete by rotation. With reduced gradient of the helical ribs this force component becomes smaller and consequently, in order to prevent movement of the reinforcing rod relative to the concrete, it is of great advantage to increase the twisting of the rod in accordance with the present invention.

Conventional reinforcing rods with transversal ribs have the ribs arranged in a distance from each other which is about equal to 0.7 times the diameter or maximum dimension of the cross-section of the reinforcing rod, in order to enforce a desirable formation of cracks in the concrete; that is to obtain as many cracks as possible, which are, consequently, of small width. The same effect can be achieved by a reinforcing rod which is strongly twisted in accordance with the present invention, if the number of longitudinal ribs which are equally spaced from each other in circumferential direction is chosen in relation to the pitch of the helical ribs obtained after twisting in such a way that the distance between adjoining ribs deformed by twisting into helical ribs, amounts to approximately 0.7 times the diameter or maximum dimension of the cross-section of the steel rod. This is achieved by arranging, for instance, four equally spaced ribs around the circumference of the rod and twisting to an extent that the pitch of the helical ribs amounts to three times the diameter of the rod, or if, for instance, the pitch is to be four times the diameter, six ribs have

to be arranged around the circumference of the rod to achieve the same result.

It is advantageous to use as raw material for the forming of concrete reinforcing steel rods, in accordance with the method of the present invention, a Thomas steel which has been produced with the addition of oxygen to the air blast. Due to the enrichment in oxygen content, the nitrogen content of the steel is reduced to values below those found in regular Thomas steel. This low nitrogen-content steel is especially suitable to withstand the high twisting operation performed in accordance with the present invention. Preferably the nitrogen content of the steel is kept below 0.012%. Obviously different types of Thomas steel in which the nitrogen content has been lowered by various processes can also be used, as well as open hearth steel.

Referring now again to the drawings, Figs. 3, 4 and 5 show a steel rod of initially circular cross-section before and after deformation in accordance with the present invention. The steel rod blank having a diameter a as shown in Fig. 3 is deformed in the direction of diameter a to an extent exceeding 30%. As shown in Fig. 4, diameter a has been reduced to diameter a_1 for the main body of the deformed steel rod, and to diameter a_2 for the ribs rolled on the main body of the steel rod. In Fig. 5, b indicates the fillet area connecting the ribs with the main body of the steel rod, which area in accordance with the present invention is deformed to a degree exceeding the degree of deformation of the steel rod, preferably to a degree of between 30 and 60%, and in which area recrystallization and release of stress is achieved during the subsequent tempering process.

Figs. 6, 7 and 8 show the deformation and formation of ribs on a steel rod blank of initially oval cross-section. The original steel rod has a longest axis c and a shortest axis d as shown in Fig. 6. The rod is cold-deformed so as to reduce the longest axis c to c_1 for the main body of the steel rod and to c_2 for the ribs rolled on the main body. This reduction in length of the longest axis of the original steel rod, as shown in Fig. 7, exceeds 30%. As shown in Fig. 8 two longitudinal ribs and a plurality of transversal ribs were rolled on the main body of the steel rod. The fillet areas connecting the ribs with the main body of the rod which in accordance with the present invention have been deformed to a degree exceeding the deformation of the main body of the rod are indicated in Fig. 8 by the letter e . The difference in the degree of deformation between these areas e and the main body of the steel rod is such that upon tempering at temperatures between 450 and 600° for a period of time of 15 to 90 minutes, recrystallization takes place in the areas e only and not in the main body of the steel rod. The upper limit of tempering temperature is chosen in accordance with the degrees of deformation actually applied, but in any event not to exceed 600° C. so as to prevent recrystallization in the main body of the steel rod.

In the cross-sectional view shown in Fig. 9 of a deformed steel rod having straight longitudinal ribs equally spaced from each other in circumferential direction, the areas of greater deformation connecting the ribs with the main body of the steel rod are indicated by the letter f .

Fig. 10 shows a steel rod having helical ribs formed on its surface by the process of twisting a steel rod having longitudinal ribs equally spaced from each other in circumferential direction. It specifically shows the relationship between the diameter g of the steel rod, the distance of adjoining helical ribs from each other, and the pitch of the helical ribs. In the illustrated embodiment shown in Fig. 10, the distance between adjoining helical ribs is equal to 0.7 times the diameter of the steel rod and the pitch of the helical ribs equals 4 times the diameter of the steel rod. The high twist of the steel rod and the consequently relatively small pitch of the ribs causes

concrete to adhere to the steel rod in a manner similar to the adherence of concrete to steel reinforcing rods provided with transversal ribs.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimension in one cross-sectional direction by at least 40%; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, and forming ribs on said steel rod not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

2. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40% and forming ribs on said steel rod; thereafter tempering said cold-rolled deformed steel rod with said ribs thereon at a temperature ranging between 450 and 600° centigrade for at least 15 minutes, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

3. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; thereafter tempering said cold-rolled deformed steel rod at a temperature of approximately 500° centigrade for between 15 and 90 minutes, and forming ribs on said steel rods not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

4. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, and forming ribs on said steel rod not less than 15 minutes before termination of said tempering, thereby deforming the area connecting said ribs with said steel rod to a degree of between 40% and 60% thus causing recrystallization and relieving of stress in said area, and tempering said cold-rolled deformed steel rod with the ribs thereon for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

5. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, forming straight longitudinal ribs on said steel rod; and twisting the so formed rod so that each of said straight

longitudinal ribs is deformed into a helical rib, not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

6. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, forming straight longitudinal ribs on said steel rod; and twisting the so formed rod so that each of said straight longitudinal ribs is deformed into a helical rib, having a pitch of less than six times the maximum dimension of the cross section of said deformed steel rod, not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

7. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, forming straight longitudinal ribs on said steel rod; and twisting the so formed rod so that each of said straight longitudinal ribs is deformed into a helical rib, having a pitch of between two and six times the maximum dimension of the cross section of said deformed steel rod, not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

8. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; forming straight longitudinal ribs on said steel rod equally spaced from each other in circumferential direction; twisting the so-formed rod so that each of said straight longitudinal ribs is deformed into a helical rib the distance of the thus formed helical ribs from each other being about 0.7 times the maximum dimension of the cross section of said deformed steel rod; and thereafter tempering said steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, whereby by a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

9. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel of oblong cross section thereby deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40% and to form a circular cross section; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, and forming ribs on said steel rod not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

10. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; forming straight longitudinal ribs on said steel rod equally spaced from each other in

circumferential direction; twisting the so-formed rod so that each of said straight longitudinal ribs is deformed into a helical rib, the pitch of said helical ribs being less than 6 times the maximum dimension of the cross section of said deformed steel rod; and thereafter tempering said steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

11. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel having an oblong cross section and deforming the same so as to reduce its dimensions in one cross sectional direction by at least 40% and to form a circular cross section; forming straight longitudinal ribs on said steel rod equally spaced from each other in circumferential direction; twisting the so-formed rod so that each of said straight longitudinal ribs is deformed into a helical rib, the distance of the thus-formed helical ribs from each other being equal to about 0.7 times the diameter of said deformed steel rod and the pitch of said helical ribs being less than 6 times the diameter of said deformed steel rod; and thereafter tempering said steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

12. A method of manufacturing ribbed steel rods made of Thomas steel having a nitrogen content of not more than 0.012% for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel having a nitrogen content of not more than 0.012% and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40%; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, and forming ribs on said steel rod not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs

thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

13. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel in two directions normal to each other and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40% and to form a rectangular cross-section; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, and forming ribs on said steel rod not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

14. A method of manufacturing ribbed steel rods for reinforcing concrete comprising the steps of cold-rolling a steel rod consisting of Thomas steel in two directions normal to each other and deforming the same so as to reduce its dimensions in one cross-sectional direction by at least 40% and to form a rectangular cross-section; thereafter tempering said cold-rolled deformed steel rod at a temperature ranging between 450° and 600° centigrade for at least 15 minutes, and forming transversal ribs on at least two opposite surfaces of said steel rod not less than 15 minutes before termination of said tempering so that said cold-rolled deformed steel rod with said ribs thereon is tempered for at least 15 minutes at the indicated temperature, whereby a ribbed steel rod of high elastic limit and high notch impact tenacity is formed.

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