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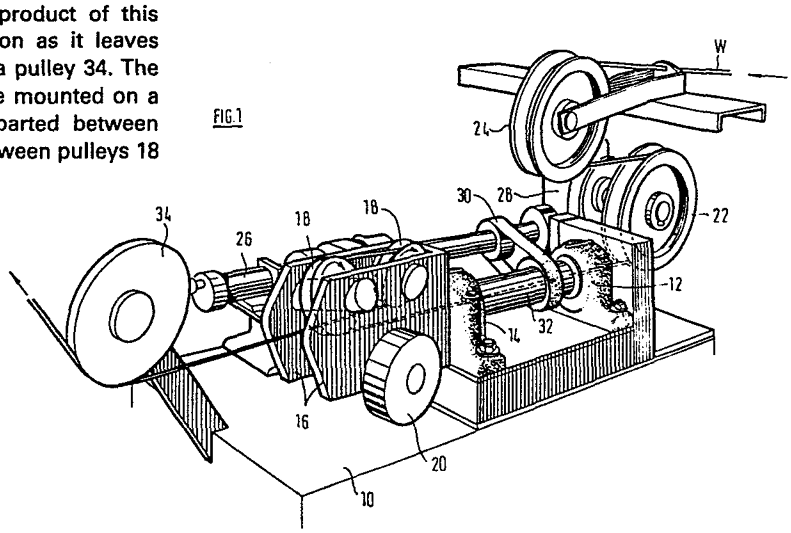
(54) Steel reinforcement rod and process for producing this rod.

(57) A process for producing steel reinforcement rod for concrete by cold working comprises feeding an indefinite length of the rod through a cold working station at which the rod is twisted in one direction about its axis and is then untwisted. The invention extends to the product of this process. The rod enters the twisting station as it leaves pulley 22 and leaves the twisting station via pulley 34. The rod also passes round pulleys 18 which are mounted on a rotatable carriage 16 so that twist is imparted between pulleys 22 and 18 and untwisting occurs between pulleys 18 and 34.

FIG.1



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Steel Reinforcement Rod and process for producing this rod

The invention relates to a process for producing reinforcement rod by cold working and to a steel reinforcement rod produced by cold working.

It is known that the cold working of steel rod improves its mechanical properties, in particular its tensile strength, and such cold working is usually effected either by rolling or drawing. Thus in the production of steel rod for use in forming welded mesh for concrete reinforcement, the material may initially be hot rolled and then cold drawn or cold rolled in order to achieve the necessary standard specification relating to its tensile strength. Such specifications usually require a minimum proof stress of 485 N/mm^2 and state that the ratio of the ultimate tensile stress to the proof stress shall be more than a specified value. For rod used in concrete reinforcing meshes the ratio specified is 1.05:1 in most European specifications.

Such rods may have a smooth surface or may be provided with surface deformations such as ribs to improve their keying or bonding capability to the concrete.

The most convenient way of introducing surface deformations such as ribs is during the hot working stage, but these deformations do not survive the normal cold working techniques of cold drawing or cold rolling. Deformations can be introduced during a final cold rolling operation but their production requires excessive local working of the material and there is a high mechanical energy requirement. It is difficult or impossible to provide suitable deformations in a cold drawing operation.

It is known to hot roll deformations into reinforcing material, to cut the material into bars of finite length and then cold work by twisting. This procedure is not suitable for long lengths of rod which are normally stored in coil form. It can be very expensive to cold twist finite lengths of rod because of the large amount of handling required during the twisting operation of finite lengths and because material is wasted when the twisted lengths are subsequently cut into shorter lengths and residual lengths are wasted.

It is also known from British Steel Corporation U.K. Patent Specification 1453233 that in cold working finite lengths of steel bar by a twisting operation, it can be beneficial to follow twisting in one direction with a degree of twisting in the opposite direction.

It is also known from West German Patent Specification 909562 that prior to cold working of a length of rod by drawing it through a die into wire, scale can be removed from the surface of the rod by a small degree of twist in one direction followed by a small degree of twist in the opposite direction in an indefinite length of rod. The German patent specification recognises that a small degree of undesired cold working might occur during the twisting and untwisting operation but this cold working is insufficient to prevent the rod from being drawn into wire immediately following the twisting and untwisting.

An object of the present invention is to provide a process for economically and effectively cold working steel rod to produce reinforcement rod, that is by avoiding the expense of wire drawing, avoiding the difficulties of producing a ribbed surface by cold rolling and avoiding the difficulties of handling finite lengths associated with cold twisting. It is also an object of the invention to provide an improved cold worked reinforcing rod.

According to one aspect of the invention there is provided a process for producing reinforcement rod by cold working of an indefinite length of steel rod, characterised in that the rod is passed through a cold working station at which it is twisted in one direction about its axis and is then untwisted. By carrying out twisting followed by untwisting in a cold working station through which the rod is fed in an indefinite length, the ends of the rod, which are normally carried in a coil or connected to plant to or from which the rod is fed in a continuous length, do not have to be twisted so that they are compatible with these end conditions.

Preferably the degree of twist, prior to untwisting is at least one turn in a length equal to thirty rod diameters. In refering to rod diameters in connection with a rod which may not be circular, the measurement intended is the notional diameter of a circular rod having the same cross-sectional area as the rod under consideration. Normally, the degree of twist will lie between one turn in five diameters and one turn in twenty diameters. The degree of twist is selected in relation to the composition and properties of the untwisted rod so that it increases the proof stress to a desired level without reducing the ductility of the rod below specification requirements.

The invention is particularly applicable to steel rod having a carbon content of not more than 0.3% by weight because low carbon steel can be manufactured readily, can easily be welded into mesh but normally requires cold working to give it sufficient strength for concrete reinforcement purposes. In a typical case the degree of twist should be chosen in relation to carbon content of the steel to result in a proof stress after ageing of between 450 and 540N/mm^2 according to the appropriate specification requirements.

At the cold working station, the rod may be passed round a pulley system having one or more rotatable pulleys around which the rod runs continuously from an input side to an output side thereof, the pulley system being orbited about an axis other than the axis of rotation of the or each pulley whereby the rod is twisted in one direction at the input side of the pulley system and is then untwisted at the output side thereof.

The rod may be fed over a restraint pulley before it enters the input side of the pulley system whereby the rod is twisted in one direction between the restraint pulley and the pulley system as the rod enters the input side thereof and is then untwisted as it leaves the output side of the pulley system.

Both the orbiting pulley system and the restraint pulley may be driven in synchronism with each other whereby the speed of orbiting of the pulley system is at a predetermined rate with respect to the speed of input of the rod to the pulley system from the restraint pulley.

According to a second aspect of the invention there is provided steel reinforcement rod which has been cold worked by twisting characterised in that the reinforcement rod has been produced by passing an indefinite length of rod through a cold working station at which the rod is twisted in one direction about its axis and is then untwisted. The degree of twisting, prior to untwisting should be at least one turn in a length equal to thirty diameters and should preferably be between one turn in five diameters and one turn in twenty diameters.

Conveniently the steel employed contains less than 0.3% carbon. The steel may be the product of an electric arc furnace. The degree of twisting, in relation to the composition and properties of the initial rod may be such as to produce a proof stress after ageing of between 450 and 540 N/mm^2 according to the appropriate specification requirements.

It is a common property of cold worked steel that its strength increases with ageing. With many cold worked steel rods, there is a tendency for the proof stress to increase with ageing more rapidly than the ultimate tensile strength. This can produce an unsatisfactory product because it is important to ensure that the ultimate tensile strength is at least 5% above the proof stress both to comply with specifications and to reduce the risk of a sudden fracture. It has been found that by the process of the invention, there is a tendency for the proof stress to increase more slowly with age than the corresponding increase in ultimate tensile stress.

Employment of the present invention in relation to steel rod which has a ribbed surface is particularly advantageous because the cold working can be carried out after the ribs have been formed by hot rolling.

The twisting and untwisting operation not only improves the mechanical strength of the rod but also effectively descales it and straightens it.

Other features of the invention will become apparent from the following description given herein solely by way of example with reference to the accompanying drawings wherein:

Figure 1 is a somewhat diagrammatic perspective view of an apparatus for effecting cold working of a steel rod by twisting to produce reinforcement rod;

and

Figure 2 is a graph showing tensile strength of the cold worked rod plotted against days of ageing at 20°C.

The following description is with reference to a steel rod, which may have either a smooth or ribbed surface, and which is suitable for use, when cut to length, in the production of welded reinforcing mesh for concrete. The rod to be cold worked is produced by conventional steel making methods and subsequently hot rolled to a typical diameter of 6 mm and, after cooling, is formed into a normal hot rolled coil. The rod is then fed continuously from the stock coil through a cold working apparatus as illustrated in figure 1 in such manner, in accordance with the invention, as to increase the proof and ultimate tensile stress to specification requirements and maintain the ratio of the ultimate tensile stress to the proof stress of the rod at or above 1.05 after ageing.

As illustrated in figure 1, the apparatus includes a fixed frame 10 upon which are mounted two plummer block bearings 12 and 14 for a hollow rotatable shaft 32. Each of the bearings 12 and 14 is centrally apertured with the apertures in alignment with each other. Outboard of the bearing 14, a stirrup shaped yoke is mounted on the end of the shaft 32, the yoke including two opposed parallel side plates 16 between which are mounted two freely rotatable pulleys 18. The pulleys 18 are carried in the yoke adjacent one edge thereof whilst at the other edge counter-balance weights 20 are mounted. In this embodiment the axes of the pulleys 18 are skewed slightly relative to each other to either side of an axis normal to the axis of shaft 32.

At the input side of the apparatus there is a relatively large diameter driven restraint pulley 22 the lower edge of which is in alignment with the axis of the bearings

12 and 14. A V-groove in pulley 22 provides drive between the rod and pulley. Rod curved round the pulley acts as a lever arm to hold it against rotation of the pulley. Located above and forward of the restraint pulley 22 is a freely rotatable guide pulley 24 onto which is fed the rod W from a convenient source such as a reel thereof. The direction of input of the rod W is shown by the arrow in the drawing.

At the rear of the apparatus there is mounted an air or electrically actuated controllable torque motor 26 which drives the restraint pulley 22 through a suitable gear box 28. The motor 26 is also coupled to rotate the shaft 32 and the yoke so that the rotatable pulleys 18 carried thereon are orbital about the axis of the bearings 12 and 14. The pulley system is thus driven in synchronism with the restraint pulley 22 to provide a predetermined speed of orbiting with respect to the speed of input of the rod over pulley 22.

The rod is pulled through the apparatus, for example from a rotating spool. If the rod is arranged to grip the restraint pulley 22 it transmits energy via the gear box 28 to the shaft of the motor 26 and hence to the yoke shaft 32, to contribute to the energy required for twisting.

In use, the rod W to be cold worked runs from a stock reel thereof around the two pulleys 24 - 22, through the hollow rotatable shaft 32, and around both pulleys 18 in the pulley system before exiting around a reaction pulley 34. The rod meets up with the pulley 34 at a point on the axis of shaft 32. Thus the output of the rod at pulley 34 is co-axial with its input from pulley 22. Rod leaving pulley 34 at an angle acts as a lever arm to hold the rod against rotation. The rod passes continuously through the apparatus and is twisted in one direction between the restraint pulley 22 and the orbiting pulley system and is then twisted in the opposite direction as it passes between the output side of the pulley system and the reaction pulley thereby imparting a substantial degree of cold working to the rod.

Cold worked rod produced by the apparatus is particularly suitable for use in concrete reinforcing mesh where cut lengths of the cold worked rod have to be welded together. In particular the rod fed through the apparatus may be ribbed transversely, as is known practice in use of reinforcing rod for concrete, and the skewed axes of the orbiting pulleys 18 particularly ensure that such ribbed rod does not snag or chafe upon itself between the input and output sides of the pulley system. Also the rod is effectively descaled and straightened whereby it may be immediately cut and welded for use in concrete reinforcing mesh.

Alternatively the rod may be coiled immediately after cold working and then uncoiled and straightened in a conventional manner prior to use in mesh manufacture. The re-straightening only slightly impairs the properties of rod which has been cold worked in accordance with the invention and then aged, provided that during the straightening operation the rod is not cold worked more than is necessary to straighten it.

It will be appreciated that other arrangements of pulleys may be provided in the pulley system provided that they are orbitable in the manner hereinbefore described; in particular it may be convenient to provide three separate freely rotatable pulleys in the pulley system having their axes of rotation parallel to one another and normal to the orbital axis of the pulley system. Also, although not illustrated herein, it may be possible to utilise a single pulley in the yoke in which case it may be convenient to provide such pulley with a frusto-conical surface to avoid snagging or chafing of the rod as it passes around the pulley. It may be possible to use an orbital guide system other than pulleys, provided it deflects the rod from its input and output axes so that the orbital motion imparts twist to the rod. However pulleys are preferred in the interests of low friction.

The invention is of particular application to low carbon steel containing up to about 0.3% carbon. The invention has the advantage of enabling a high proof stress and a suitable excess of ultimate tensile stress over proof stress to be achieved, particularly after ageing, even with low carbon steel from an electric arc furnace. This type of steel is not normally suitable for work hardening by cold drawing which is the conventional procedure for work hardening continuous lengths of rod because the free nitrogen content results in excessive work hardening in that the proof stress becomes too high a proportion of the tensile stress after ageing.

The nature of the apparatus is such that the degree of twist in both directions is equal so that the second twisting operation could be thought of as an untwisting operation. The degree of twist affects the properties of the final material. Greater twisting leads to a higher proof stress but a smaller margin between ultimate tensile and proof stresses. The degree of twist should be just sufficient to achieve the required proof stress and depends on the composition of the hot rolled material. For a typical rod, a pitch of less than 30 rod diameters should be employed. The preferable range if 5 to 20 diameters. The degree of twist is controlled by varying the relationship between the rate of orbiting of the pulley system and the rate of passage of rod through the apparatus. A standard specification for reinforcement rod requires a minimum of 0.2% proof stress of 485 N/mm^2 so it is desirable to select a degree of twist of this order, a little above the minimum needed to meet the specification.

It is believed that the cold working associated with the twisting and untwisting of the rod moves dislocations from local concentrations of free nitrogen and other interstitially dissolved elements and thereby work hardens the material. Because the slip planes associated with the cold working do not correspond to slip planes associated with applied tension, the migration of dislocations along the slip planes associated with cold working during ageing has a limited effect on the increase in longitudinal proof stress with age. This in turn prevents the proof stress approaching too closely to the ultimate tensile stress during the ageing process.

The shear strain during twisting is at a maximum near the surface of the rod and reduces towards the centre of the rod. Despite this, a major part of the cross-section of the rod is work hardened to a substantial extent.

The following example illustrates the properties achieved by the twisting process of the invention.

A hot rolled steel rod with a nominal diameter of 6 mm has the following composition: Carbon 0.08%, Silicon 0.15%, Manganese 0.52%, Copper 0.42%, Sulphur 0.04%, Phosphorus 0.03%, remainder iron and incidental impurities. In the as-rolled condition this rod had the properties set out in row 1 of the table (see below). This rod was then passed through the machine described with reference to figure 1 and during the twisting a tension of 3560 N was applied to the rod in the twisting zone. The degree of twist, followed by untwisting, was 360° in a length of 73.11 mm, that is a pitch of 12 diameters. The rod was then aged for two hours at 100°C at which stage it had the properties set out in row 2 of the table. The decrease in diameter indicates a corresponding increase in length which was brought about by the tension in conjunction with the twisting. Although the excess of ultimate tensile stress over proof stress was decreased by the twisting operation, it still remained at a very satisfactory level.

Condition	Diameter mm.	Proof/Stress N/mm^2	U.T.Stress N/mm^2	Excess of U.T. over Proof Stress %	Elongation %
1.As rolled	6.0925	311	431	38.6	18
2.Twisted & aged	5.82	510	566	10.8	12

Figure 2 is a graph wherein the 0.2% proof stress, the ultimate tensile stress and the percentage excess are plotted against days of ageing of a 6 mm nominal diameter steel rod corresponding to the rod described above, initially produced by hot rolling and then fed through the apparatus of figure 1 and twisted and untwisted with a pitch of 12 diameters under a tension of 2670 N. The graph shows that the ultimate tensile stress of the rod rises at a faster rate with ageing than does the proof stress thus leading to an increase, with ageing, of the percentage excess. During the twisting and untwisting under tension, the rod diameter decreased from 6.09 to 5.89 mm.

Thus cold worked rod produced in accordance with the invention to meet standard specifications will continue to meet the standard specifications relating to tensile strength such as are particularly laid down for the production of steel rod for use in welded reinforcing mesh for concrete. The low carbon content of the steel which can be used also results in very good weldability so that strong welds are produced easily without detracting significantly from the strength of the rod.

CLAIMS

1. A process for producing reinforcement rod by cold working of an indefinite length of steel rod, characterised in that the rod is passed through a cold working station at which it is twisted in one direction about its axis and is then untwisted.

2. A process according to claim 1 characterised in that the degree of twist, prior to untwisting, is at least one turn in a length equal to 30 rod diameters.

3. A process according to claim 2 characterised in that the degree of twist lies between 1 turn in 5 diameters and 1 turn in 20 diameters.

4. A process according to any preceding claim characterised in that the rod has a carbon content of not more than 0.3% by weight.

5. A process according to any preceding claim wherein the degree of twist is selected to give a 0.2% proof stress after ageing of between 450 and 540 N/mm^2.

6. A process according to any preceding claim wherein the rod has a ribbed surface .

7. A process according to any preceding claim wherein, at the cold working station, the rod is passed around a pulley system having one or more rotatable pulleys around which the rod runs continuously from an input side to an output side thereof and wherein the pulley system is orbited about an axis other than the axis of rotation of the or each pulley whereby the rod is twisted in one direction at the input side of the pulley system and is then untwisted at the output side thereof.

8. A process according to claim 7 wherein the rod is fed over a restraint pulley before it enters the input side of the pulley system whereby the rod is twisted in one direction between the restraint pulley and the pulley system as the rod enters the input side thereof and is then untwisted as it leaves the output side of the pulley system.

9. A process according to claim 8 wherein both the orbiting pulley system and the restraint pulley are driven in synchronism with each other whereby the speed of orbiting of the pulley system is at a predetermined rate with respect to the speed of input of the rod to the pulley system from the restraint pulley.

10. Steel reinforcement rod which has been cold worked by twisting characterised in that the reinforcement rod has been produced by passing an indefinite length of rod through a cold working station at which the rod is twisted in one direction about its axis and is then untwisted.

11. Steel reinforcement rod according to claim 10 characterised in that the degree of twist, prior to untwisting is at least one turn in a length equal to 30 diameters.

12. Steel reinforcement rod according to claim 11 characterised in that the degree of twist lies between 1 turn in 5 diameters and 1 turn in 20 diameters.

13. Steel reinforcement rod according to any one of claims 10 to 12, characterised in that the steel contains less than 0.3% carbon by weight.

14. Steel reinforcement rod according to claim 13 characterised in that the steel for the rod has been

produced in an electric arc furnace.

15. Steel reinforcement rod according to any one of claims 10 to 14 characterised in that it has a 0.2% proof stress after ageing of between 450 and 540 N/mm^2.

16. Steel reinforcement rod according to any one of claims 10 to 15 characterised in that the ratio of ultimate tensile stress to proof stress of the reinforcement rod does not decrease with ageing.

17. Steel reinforcement rod according to any one of claims 10 to 16 characterised in that the rod has a ribbed surface.

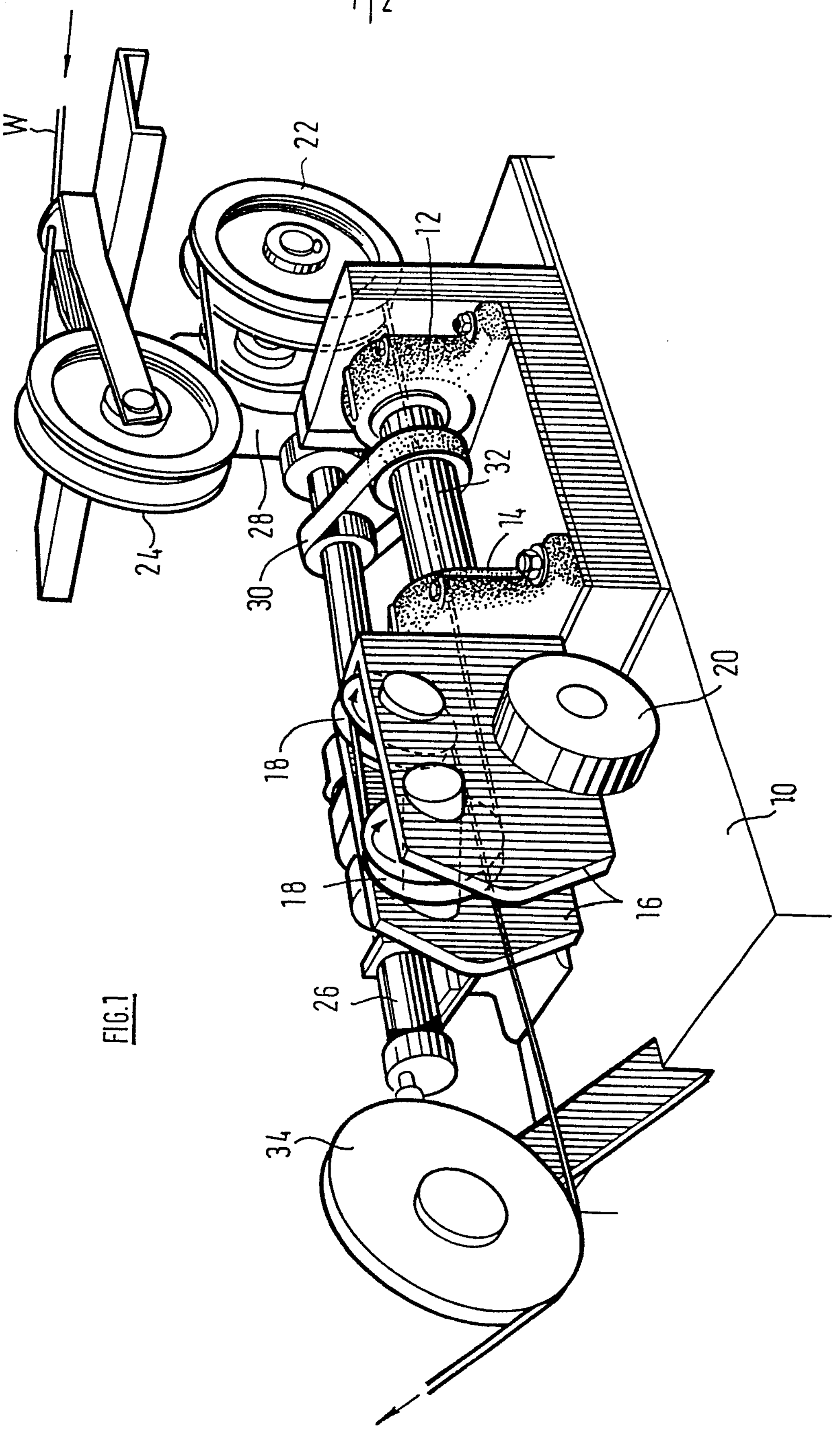
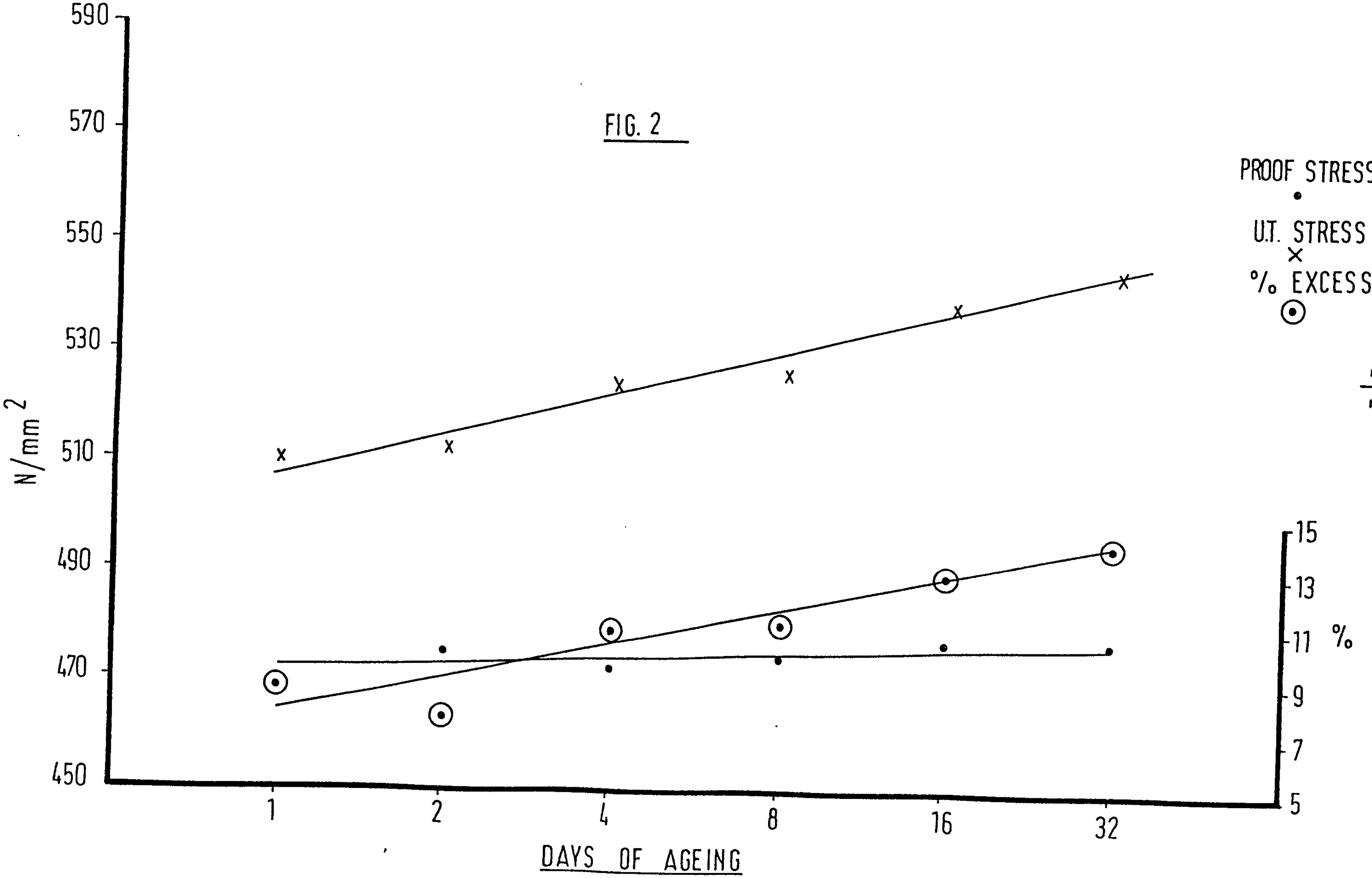


FIG.1

FIG. 2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EUROPEAN SEARCH REPORT

0080833
Application number

EP 82 30 6142

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
D,A	DE-C- 909 562 (KOLLING)		B 21 C 37/00 B 21 D 11/15
D,A	GB-A-1 453 233 (BRITISH STEEL)		
X	US-A-4 075 880 (COPELAND) * Claims 1-3; figure 1 *	1,7	
X	GB-A-1 442 097 (VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE) * Claims 1, 4, 5; figure 1 *	1,7	
Y	DE-C-1 009 586 (THOMAS) * Claims 1-3; figure 1 *	1	TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
Y	FR-A-1 565 871 (REHM) * Claims 1, 2, 3; figures 1, 4 *	1	B 21 C 37/00 B 21 C 43/00 B 21 D 3/00 B 21 D 11/00
A	DE-A-1 452 201 (ALBERT)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	01-02-1983	SCHLAITZ J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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