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(54) **METHOD AND DEVICE FOR PLASTIC STRETCHING OF A METAL WIRE**

(57) The present invention relates to a method for plastic stretching of metal wires and a stretching device. The stretched wires are used amongst others to produce concrete reinforcements and concrete constructions.

The method comprises (a) providing a metal wire; (b) measuring the diameter of the metal wire; plastic stretching of the metal wire provided in step (a) and measured in step (b) by means of at least two rotating shafts, whereby the distance or tension between the rotating shafts can be adjusted, thus obtaining a stretched metal wire; (d) measuring the diameter of the stretched metal wire; and (e) controlling the distance or tension between the rotating shafts in step (c) based on the diameter of the metal wire measured in step (b) and the diameter of

the stretched metal wire measured in step (d).

The stretching device comprises at least an unrolling device for unrolling the metal wire; at least one measurement device for measuring the diameter of the metal wire; a stretching station comprising at least two rotating shafts, wherein the distance or tension between the rotating shafts is adjustable, wherein incoming metal wire is stretched to obtain a stretched metal wire; at least one measuring device for measuring the diameter of the stretched metal wire; control of the distance or tension between the at least two rotating shafts from the measurement device for the metal wire and the stretched metal wire; and a drawing plate for driving the metal wire.

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Description

Field of the Invention

[0001] The present invention concerns a method for plastic stretching of metal wires. The stretched wires are used amongst others for producing concrete reinforcements and concrete constructions.

Background of the Invention

[0002] Metal wire is an important raw material in industry and construction. In order to be useable, the wires must however possess certain properties. The wires must be sufficiently deformable and be able to tolerate a high tensile stress.

[0003] To obtain metal wires with both these properties, the wires typically undergo various processing steps such as stretching, rolling, and post-stretching.

[0004] Stretching of metal wire is a forming technique in which a metal wire is elongated. When a metal wire is loaded, it stretches. There are typically two types of stretch. With elastic stretching, the metal wire is loaded within its limit of elasticity. The elongation disappears when the load is removed. The value of elastic elongation depends on the metal wire and the load percentage, but under normal circumstances is around 0.20 to 0.60%. Plastic stretching is permanent and occurs when the load exceeds the limit of elasticity. Plastic stretching of metal wires is achieved using generally known techniques and for example by conducting the metal wire over various rotating shafts. Plastic stretching of a metal wire may be used to change the cross section of the wire. In this way, the mechanical properties of the wire can also be modified. Characteristic mechanical properties of a metal wire include amongst others the elongation at maximum load (Agt), the tensile strength (Rm) and the limit of elasticity (Re). The limit of elasticity is the point during a tensile test at which the first kink appears in the stress-elongation diagram. At heavier loads on the metal wire, the graph deviates from the straight line. A measure of the elasticity is implicit in the Agt value. The higher the Agt, the more the wire can be stretched elastically. Conversely, if a wire has a low Agt value, it can only be stretched elastically to a small extent.

[0005] Typically, the wire diameter and hence also the weight of the metal wire are not uniform over the entire length of the wire. Due to the spread of the wire weight, there is a risk that at specific points, the wire will not have the minimum weight. This is typically countered by producing wires with a significant margin above the required minimum value. The provision of a margin however results in a loss because, for the same weight of metal, a wire of shorter length is obtained. It is therefore desirable to keep the margin as low as possible and to limit the variation in diameter of the metal wire. There is thus a need for methods for plastic stretching of metal wires which allow these losses to be minimized.

Summary of the Invention

[0006] The present invention relates in general to a method for plastic stretching of a metal wire. This method allows the spread of variation of the wire diameter to be limited to a minimum and hence limits material losses.

[0007] In general, the present invention provides a method or process for adjusting the diameter of a metal wire. The adjustment in diameter is monitored by means of an in-line measurement and adjusted on the basis of one or more measurements of the diameter of the metal wire. At least one of the measurements is made after the change of diameter, and this measurement gives feedback to the device which achieved the reduction in diameter of the metal wire so that the reduction in diameter can be monitored precisely, and whereby the variation in diameter of the metal wire is reduced as well.

[0008] More specifically, the present invention provides a method for plastic stretching of a metal wire comprising:

- (a) providing a metal wire;
- (b) measuring the diameter of the metal wire;
- (c) plastic stretching of the metal wire provided in step (a) and measured in step (b) by means of at least two rotating shafts, whereby the distance or tension between the rotating shafts can be adjusted, thus obtaining a stretched metal wire;
- (d) measuring the diameter of the stretched metal wire;
- (e) controlling the distance or tension between the rotating shafts in step (c) based on the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d).

[0009] Preferably steps (a) to (e) are performed continuously, and in addition, the metal wire is preferably transported continuously at a speed between 50 m/min to around 1000 m/min.

[0010] In a particular embodiment, the method described herein provides that the stretched metal wire is driven by a drawing device positioned after the stretching device which performs step (c).

[0011] Preferably the metal wire provided in step (a) is a hot-rolled metal wire.

[0012] The method described herein further provides providing a smooth metal wire provided in step (a), preferably a smooth hot-rolled metal wire. Alternatively, the metal wire provided in step (a) may be a profiled metal wire, preferably a profiled hot-rolled metal wire.

[0013] Preferably, the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d) are measured by an optical measurement. Preferably the optical measurement of the diameter is derived from the distance between the edges of the metal wire or the distance between the profiles of the metal wire.

[0014] In a particular embodiment, the present inven-

tion provides a method in which the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d) are measured by measurement of the speed of the metal wire in step (b) and the speed of the stretched metal wire in step (d).

[0015] Preferably the method described here for plastic stretching in step (c) causes an elongation of metal wire of at least 1%. Also the method described here for plastic stretching in step (c) reduces the variation in diameter of the stretched metal wire to at most 1%.

[0016] In a particular embodiment, the method described herein comprises one or more additional steps selected from:

- unrolling of the metal wire;
- stripping of the metal wire;
- coating of the metal wire and/or the stretched metal wire;
- application of a profile to the metal wire or stretched metal wire;
- cooling of the stretched metal wire;
- stress relief of the stretched wire; and/or
- winding of the stretched metal wire.

[0017] Preferably the method described herein comprises unrolling the metal wire at the starting position and rolling up the metal wire at the end position, wherein between unrolling and rolling up, the metal wire undergoes at least one of the following steps:

- measuring the diameter of the metal wire;
- plastic stretching of the metal wire by means of at least two rotating shafts, wherein the distance or tension between the rotating shafts can be adjusted, thus obtaining a stretched metal wire;
- measuring the diameter of the stretched metal wire;
- controlling the distance or tension between the rotating shafts in steps based on the diameter of the metal wire and the diameter of the stretched metal wire;
- driving of the stretched metal wire; and
- stress relief of the stretched metal wire.

[0018] The present invention also concerns a stretching device comprising at least:

- an unrolling device for unrolling the metal wire;
- at least one measurement device for measuring the diameter of the metal wire;
- a stretching station comprising at least two rotating shafts, wherein the distance or tension between the rotating shafts is adjustable, wherein incoming metal wire is stretched to obtain a stretched metal wire;
- at least one measuring device for measuring the diameter of the stretched metal wire;
- a controller for controlling the distance or tension between the at least two rotating shafts from the meas-

urement device for the metal wire and the stretched metal wire; and

- a drawing plate for driving the metal wire.

[0019] The method described herein provides in-line measurement of the rotating shafts which provide the plastic stretching, based on in-line measurement of the wire diameter. In this way the spread of wire diameter may be limited, irrespective of the type of metal wire. Thus a maximum wire length/wire weight ratio can be achieved while the minimum required wire diameter remains guaranteed.

[0020] These and further aspects and embodiments of the invention are explained in more detail in the sections below and in the claims, and are illustrated by the non-limitative examples.

Brief Description of the Figures

[0021] Figure 1 illustrates diagrammatically a specific embodiment of the method described here.

Detailed Description of the Invention

[0022] Before describing the present method and devices used in the invention, it must be understood that this invention is not limited to specifically described methods, components or devices, since evidently, such methods, components and devices may vary. It must also be understood that the terminology used herein is not intended to restrict, as the area of application of the present invention is limited only by the attached claims.

[0023] Unless specified otherwise, all technical and scientific terms used herein have the same meaning as generally understood by an expert in the field to which this invention relates. Although in practice or on testing of the present invention, all methods and materials which are comparable or equivalent to those described here may be used, the preferred methods and materials are now described.

[0024] As used herein, the singular forms "a" and "the" cover both the singular and the plural of the objects to which reference is made, unless the context clearly specifies otherwise.

[0025] The terms "comprising" and "comprise" as used here are synonymous with "including", or "containing" or "contains", and are inclusive or open and do not exclude extra non-specified objects, elements or method steps.

[0026] The terms "comprising" and "comprise" also cover the term "consisting of".

[0027] The naming of numerical ranges by end points includes all integers and fractions which lie within the respective ranges, together with said end points.

[0028] The term "around" as used here when reference is made to a measurable value such as a parameter, a quantity, a duration or similar, includes variations of +/- 10% or less, preferably +/- 5% or less, more preferably +/- 1% or less, and even more preferably +/- 0.1% or less

of the specified value, insofar as such variations are applicable in the present invention. It must be understood that the value to which the term "around" refers, is itself also specific and is disclosed as preferable.

[0029] All documents cited in the present specification are hereby included as a whole by reference.

[0030] Unless specified otherwise, all terms used in the disclosure of the invention, including technical and scientific terms, have the meaning as generally understood by the skilled person to which this invention relates. As further aids, definitions for the terms used in the description are included, for better appreciation of the principles of the present invention.

[0031] In general, the present invention provides a method or process for adjustment and preferably reduction of the diameter of a metal wire. The adjustment and preferably reduction of the diameter is monitored by means of in-line measurement and adjusted based on one or more measurements of the diameter of the metal wire. At least one of the measurements is made after the adjustment and preferably reduction of the diameter, and this measurement gives feedback to the device which performs the adjustment and preferably reduction of the diameter of the metal wire, so that the adjustment and preferably reduction of the diameter can be precisely monitored and whereby also the variation in the diameter of the metal wire is reduced. The adjustment and preferably reduction of the diameter of the metal wire may take place in various ways, and preferably by means of (cold-) rolling, plastic stretching and wire drawing. Wire drawing is a process in which a thick metal wire is given a smaller diameter by drawing it through one or more drawing plates or dies. The drawing plates or dies have a wire drawing opening which is smaller than the diameter of the metal wire, whereby the diameter of the metal wire is reduced by the wire drawing.

[0032] Rolling is a forming technique in which a metal wire is deformed by two or more rollers. Rolling of a metal wire may be used to modify the cross section of the wire and/or apply a profile to the wire surface. Cold-rolling takes place at a temperature below the recrystallization temperature, for example at room temperature, and typically ensures an increase in the wire strength.

[0033] Plastic stretching is a forming technique wherein a metal wire is permanently elongated by loading it above the limit of elasticity.

[0034] More specifically, the present invention provides a method for plastic stretching of a metal wire. More specifically, the present invention provides a method for plastic stretching of metal wire wherein the method comprises the following steps:

- (a) providing a metal wire;
- (b) measuring the diameter of the metal wire;
- (c) plastic stretching of the metal wire provided in step (a) and measured in step (b) by means of at least two rotating shafts, whereby the distance or tension between the rotating shafts can be adjusted,

thus obtaining a stretched metal wire;

(d) measuring the diameter of the stretched metal wire;

(e) controlling the distance or tension between the rotating shafts in step (c) based on the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d).

[0035] This method is explained in more detail below.

[0036] The method described herein is particularly suitable for continuous plastic stretching of a metal wire. Here the metal wire is transported along a predefined route in a continuous manner, preferably at a speed in the range from around 10 m/min to around 1000 m/min, more preferably at a speed in the range from around 50 m/min to around 800 m/min, and most preferably at a speed in a range from around 100 m/min to around 700 m/min. The transport speed of the metal wire may for example be around 100 m/min, around 125 m/min, around 150 m/min, around 175 m/min, around 200 m/min, around 250 m/min, around 300 m/min, around 350 m/min, around 400 m/min, around 450 m/min, around 500 m/min, around 550 m/min, around 600 m/min, around 650 m/min or around 700 m/min. As the diameter of the metal wire is reduced in the present method, there is a difference between the speed of the metal wire before the stretching process and the speed of the metal wire after the stretching process. The difference in speed corresponds to the degree of elongation of the wire. An incoming speed of 60 m/min with a wire elongation between 5% and 20% results in an outgoing speed of respectively 63 m/min and 72 m/min, an incoming speed of 120 m/min with a wire elongation between 5% and 20% results in an outgoing speed of respectively 126 m/min and 144 m/min. With an incoming speed of 600 m/min and an elongation of the metal wire between 5% and 20%, the respective outgoing speed is 630 m/min and 720 m/min.

[0037] In a continuous process, the transport speed of the metal wire remains virtually constant in every step of the process. The skilled person will understand that as a result of elongating the wire, the speed with which the metal wire is transported, expressed in weight unit per time unit, typically remains constant, while the speed expressed in length unit per time unit may vary between the different steps of the process.

[0038] The term "in-line" as used here means that the metal wire passes through the various steps of the method in a continuous manner. In other words, the various steps are performed simultaneously or successively without perceptible delay. An "in-line" step of the method implies that the step is part of the continuous method.

[0039] In a first step (a) of the method according to the present invention, a metal wire is provided. The metal wire may be provided on a roll. In certain embodiments, step (a) thus includes the unrolling of a metal wire from a roll.

[0040] In certain embodiments, the metal wire provid-

ed in step (a) is a hot-rolled metal wire. Such metal wires are often used as a base product for further processing. It is however possible that the metal wire is provided in step (a) as a cold-rolled wire roll.

[0041] The metal wire provided in step (a) may have a smooth or profiled surface, preferably a smooth or profiled hot-rolled metal wire. Examples of wires with a profiled surface are ribbed, indented and lightly indented wires. Such types of wires are well-known to the skilled person. Preferably, the metal wire provided in step (a) is a smooth metal wire. In other preferred forms, the metal wire provided in step (a) is a profiled metal wire, preferably a ribbed, indented or lightly indented metal wire.

[0042] The metal wire may have any cross section such as round, square, rectangular, oval or semi-oval cross section. The metal wires according to the present invention may be selected within a wide diameter range which lies between 0.1 mm and 50 mm, preferably between 0.5 mm and 30 mm, and more preferably between 2 mm and 16 mm.

[0043] For wires with a non-circular cross section and/or a profiled surface, the term "diameter" as used here means an equivalent diameter, more specifically the nominal centre line of the wire. The term "nominal centre line" indicates the diameter of a hypothetical wire with a circular cross section, of the same length and content as the actual wire.

[0044] The metal wire is made from one or more metals or metal alloys, for example iron, steel, brass, bronze, copper, aluminium, silver, gold or platinum. In a preferred embodiment, the wire is a steel or iron wire. Steel wires may be produced from steel with high or low carbon content.

[0045] The method described herein comprises in step (b) the (in-line) determination or measurement of the cross section or diameter of the metal wire obtained from step (a) as described above. The determination or measurement of the diameter takes place as shortly as possible before the plastic stretching of the wire.

[0046] The wire may be measured in various ways.

[0047] In certain embodiments, the wire diameter is determined optically. This can be achieved by directing a set of one or more light sources (for example laser beams) in one or more directions perpendicularly onto the wire and detecting the transmitted light. One example of an apparatus based on this principle is described in patent specification EP0565090 (which is hereby incorporated). Such an apparatus allows measurement not only of the diameter but also of the ovality and/or other forming parameters of the wire.

[0048] Suitable apparatuses for measuring the diameter of a metal wire are available in the trade and available to the skilled person.

[0049] Optical measurement assemblies are usually able to perform measurements at high frequency (scans). In certain embodiments, the diameter of the metal wire is measured at least 100, at least 250, at least 500 at least 1000, at least 2500, at least 5000, or at least 10000

times per second; for example, the diameter of the metal wire is measured 4000 times per second. This is particularly advantageous in a continuous process, wherein the metal wire is transported at a high speed. In certain embodiments, the distance between two successive measuring positions on the metal wire is at most 5 cm, preferably at most 2 cm, more preferably at most 1 cm, for example every 6 mm.

[0050] In certain embodiments, the diameter may be determined in other ways, for example from the speed of the metal wire before and after the plastic stretching. The elongation of the wire, and hence also the corresponding diameter reduction, can be derived from the speed change. The speed of the metal wire can be determined via contact or contactless measurements as known to the expert. Suitable contactless measurement techniques may for example comprise laser Doppler speed measurement. Optionally, several reference measurements may be made of the wire diameter. In this way the diameter may be determined more precisely. In certain embodiments, a secondary monitoring of the wire diameter is performed using a wire drawing system.

[0051] The method described here in step (c) comprises the plastic stretching of the metal wire. Here a stretched metal wire is obtained which can be processed further if required (see below). Stretching processes for metal wires are well known to the skilled person. Herein, the wire is guided over at least two rotating shafts or rollers. The shafts or rollers may also be referred to as wheels, axles, rolls or rods. The shafts are for example pushed apart, thus applying tension to the wire, whereby when the limit of elasticity of the metal wire is exceeded, the wire is deformed and consequently the diameter of the wire is reduced. A stretching process can also be carried out by conducting the metal wire over at least two drawing rollers, wherein the second drawing roller has a diameter which is slightly larger than the first drawing roller, whereby the wire is stretched plastically. The difference in diameter ensures the occurrence of a stress on the metal wire.

[0052] In some cases the desired deformation can be obtained more simply by using more than two rotating shafts. In certain embodiments, step (c) of the method described here therefore comprises the plastic stretching of the metal wire using three, four, five, six or more rotating shafts. For example the force on the metal wire can be gradually increased.

[0053] The total deformation of the metal wire by plastic stretching generally ensures an elongation of the wire of between 0.5 and 6%, preferably between 1% and 5%, for example around 4%, relative to the wire provided in step (a).

[0054] In a preferred embodiment, the method described here is a method for cold stretching of a metal wire wherein the stretching process is carried out at a temperature below the recrystallization temperature of the metal. More specifically, the stretching process can be carried out at room temperature. Cold stretching typ-

ically results in an increase in the tensile strength of the metal wire.

[0055] The method described herein comprises in step (d) the (in-line) determining or measuring the cross section or diameter of the stretched wire obtained in step (c) as described above. The diameter is determined or measured preferably immediately after plastic stretching. By limiting the distance between the measurement in step (b) and the measurement in step (d) as far as possible, regulation of the plastic stretching is corrected in a rapid and accurate manner.

[0056] The diameter may be measured in various ways.

[0057] In certain embodiments, the diameter is determined optically. This can be achieved by directing a set of one or more light sources (for example laser beams) in one or more directions perpendicularly onto the wire and detecting the transmitted light. One example of an apparatus based on this principle is described in patent specification EP0565090 (which is hereby incorporated). Such an apparatus allows measurement not only of the diameter but also of the ovality and/or other forming parameters of the wire.

[0058] Suitable apparatuses for measuring the diameter of the stretched wire are available in the trade and available to the skilled person.

[0059] Optical measurement assemblies are usually able to perform high frequency measurements (scans). In certain embodiments, the diameter of the metal wire is measured at least 100, at least 250, at least 500 or at least 1000 times per second. This is particularly advantageous in a continuous process, wherein the metal wire is transported at a high speed. In certain embodiments, the distance between two successive measuring positions on the metal wire is at most 5 cm, preferably at most 2 cm, more preferably at most 1 cm, for example every 6 mm.

[0060] In certain embodiments, the diameter may be determined in other ways, for example from the speed of the metal wire before and after the plastic stretching. The elongation of the wire, and hence also the corresponding diameter reduction, can be derived from the speed change. The speed of the metal wire can be determined via contact or contactless measurements as known by the skilled person. Suitable contactless measurement techniques may for example comprise laser Doppler speed measurement. Optionally, several reference measurements may be made of the wire diameter. In this way the diameter may be determined more precisely. In certain embodiments, a secondary monitoring of the wire diameter is performed using a wire drawing system.

[0061] In a particular embodiment, the diameter is determined by measuring the distance between the profiles on the metal wire. Profiled metal wires comprise notches such as ribs or indentations at regular intervals. By measuring the distance between one or more profiles for the metal wire and for the stretched metal wire, it can be

determined to what extent the measured piece of metal wire has been elongated, and consequently to what extent the diameter of the metal wire has reduced.

[0062] In a further step (e), the method described herein comprises the (in-line) control of the distance or tension between the rotating shafts in step (c) on the basis of the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d). In certain embodiments, the diameter of the stretched metal wire is measured during the stretching process (after a first set of at least two rotating shafts), wherein the sets are controlled individually on the basis of the diameter measured after the stretch concerned.

[0063] The control system is typically based on the difference between a set value and the measured value, this difference also being called a "fault signal". For example, when the measured diameter exceeds the set value, the force exerted during the stretching process may be increased so that the diameter of the metal wire is reduced. Conversely, if the measured diameter is lower than the set value, the force exerted during the stretching process may be reduced so that the diameter of the metal wire increases.

[0064] The set values selected may depend on the minimum wire diameter required. Preferably the minimum required wire diameter, with an appropriate margin, is used as a set value. As the method described here allows a reduction in the spread of wire diameters, a relatively small margin suffices. A suitable margin is a margin of at most 2%, preferably at most 1% and preferably at most 0.5%. Preferably in the stretching in step (c), the variation in diameter of the metal wire is reduced to maximum 1%, preferably maximum 0.5%.

[0065] It is important that a measurement is also carried out before the stretching process so that all possible variations in diameter can be remedied.

[0066] An alternative or addition to the measurement of the cross section or diameter of the stretched wire obtained in step (c) as described above is a measurement of the ovality of a metal wire. This can also take place using the optical method described above. Determining the ovality can be important for checking the quality of the stretched metal wire. During plastic stretching, there is always the possibility that the wire will be deformed. The deformed metal wire then has a non-cylindrical cross section and the measured diameter differs from the actual diameter. Determining the ovality ensures determination of the quality of the stretched metal wire, and may reveal defects during plastic stretching.

[0067] The position of the rotating shafts or the tension between the rotating shafts is typically adjusted by motors, wherein the motors may be controlled by a regulator or controller such as a PID controller. A PID controller (PID stands for proportional-integral-derivative) is a common controller and well known to the skilled person. However, it is not excluded that, in other embodiments, a different regulator may be used. The position of the rotating shafts or the tension between the rotating shafts may

also be adjusted pneumatically or hydraulically.

[0068] In certain embodiments, the fault signal is determined from a (progressive) average of a certain number of diameter measurements. This has advantages in particular when the measurement results show a low accuracy. Measurements of profiled metal wires often have a low accuracy. More specifically, successive measurements of profiled wires may show relatively large differences because the measured diameter typically differs depending on whether the measurement is made on ribs or between ribs, or on indents or between indents. Because significant differences between measurement points, it is more useful to base the control of the rotating shafts on the average of a number of successive data points.

[0069] The diameter of the stretched wire after step (c) depends not only on the setting of the rotating shafts but also on the diameter of the metal wire provided in step (a). This diameter may also vary throughout the metal wire. In extreme cases however, it is possible that the intrinsic variation in metal wire as provided in step (a) has a non-negligible share of the variation in diameter measured after plastic stretching. This may result in a less than optimum control of the rotating shafts on the basis of measured diameter. Therefore it is provided that the diameter of the metal wire is also determined before plastic stretching. Thus it is possible, on control of the rotating shafts on the basis of the measured diameter, to make a correction for the intrinsic variation of the diameter before plastic stretching.

[0070] To guide the metal wire through the one or more sets of rotating shafts, in certain embodiments of the method described herein, an actuator for driving the metal wire is provided. Preferably the metal wire is driven by an actuator positioned after the stretching device. In this way the metal wire is drawn through the stretching device. The metal wire is preferably driven by means of one or more drawing plates or dies positioned along the production process and preferably after the stretching device.

[0071] In certain embodiments, the stretched metal wire may undergo further processes such as:

- unrolling of the metal wire;
- stripping of the metal wire;
- coating of the metal wire and/or the stretched metal wire;
- applying a profile to the metal wire or stretched metal wire;
- cooling of the stretched metal wire;
- passivating the stretched metal wire;
- stress relief of the stretched wire; and/or
- winding of the stretched metal wire, for example in a coil or a bundle.

[0072] These processes are explained briefly below.

[0073] In certain embodiments, the method described here comprises unrolling of the metal wire from a coil or bundle. Metal wire, such as for example hot-rolled metal

wire, is typically transported and stored in coils or in bundles. Similarly, the method described herein comprises winding, coiling up or rolling up of the rolled metal wire in a coil or in a bundle at the end of the process.

[0074] In certain embodiments, the method described here comprises stripping of the metal wire provided in step (a). Stripping preferably takes place as part of step (a), i.e. before plastic stretching of the metal wire. Stripping means removing any mill skin from the metal wire. Mill skin is a form of oxidation which occurs on production of new hot-rolled steel. The oxidation layer usually has a thickness of between 50 to 500 microns, depending on the rolling conditions of the steel. The presence of mill skin around the metal wire is usually undesirable because it can have a harmful effect on the processing of the wire. For example, the presence of a mill skin can hinder the welding of the wire, and the detachment of the mill skin during the stretching process may damage the equipment used in the process. The mill skin may be removed mechanically or chemically. Mechanical means for removing the mill skin comprise but are not limited to deforming, brushing and/or blasting (such as sandblasting) of the metal wire. In a preferred embodiment, the mill skin is removed by (reversible) deformation of the wire. This is known to the skilled person and is based on the principle that the metal wire is typically flexible, while the mill skin is typically brittle. Sufficient deformation (e.g. bending, torsion and/or stretching) of the metal wire results in breakage of the mill skin, and consequently the mill skin falls off the metal wire. This can take place continuously, for example by bending the metal wire over a spool. The metal wire may also be stripped after the first measurement of diameter of step (b).

[0075] In certain embodiments, the method described herein comprises coating the metal wire. More specifically, the metal wire may be provided with a lubricant. This may be applied to promote the stretching process and any stress relief. Suitable lubricants are well-known by the skilled person. In certain embodiments, the wire is provided with a drawing soap such as sodium stearate or calcium stearate. The wire may be provided with a lubricant as part of step (a), i.e. before plastic stretching of the metal wire. Preferably, the wire is provided with a lubricant after step (c), i.e. after plastically stretching the metal wire. The lubricant may be applied continuously by spraying, dipping, brushing or other techniques known to the skilled person.

[0076] In certain embodiments, the stretched metal wire may undergo a step of stress relief. Stress relief is a metal-processing method in which the diameter of the wire is reduced further to a limited extent by guiding the metal wire over a number of rollers in close succession. This process also leads to an elongation of the wire, which however is usually small relative to the elongation achieved during plastic stretching. In the method described herein, the metal wire is elongated further by stress relief by typically 0.5% in relation to the stretched wire before the wire drawing. As well as an additional

elongation of the metal wire, stress relief also ensures a recovery of a number of important parameters (Agt and Rm/Re) of the metal wire.

[0077] In certain embodiments, the method described herein may comprise a passivation step. Passivation leads to the spontaneous formation of a hard non-reactive surface film which hinders further corrosion and may be achieved by dipping the wire in one or more passivation solutions, as known by the skilled person. Passivation is usually carried out after plastic stretching and after drawing and/or stress relief of the wire.

[0078] In certain embodiments, the stretched wires (at the end of the method) are straightened. In other embodiments, the stretched wires are rolled up for storage and/or transport.

[0079] In certain embodiments, the method comprises unrolling the metal wire at the starting position and rolling up or coiling of the metal wire at the end position, and wherein the metal wire, between unrolling and coiling, undergoes at least one of the following steps:

- stripping the metal wire;
- measuring the diameter of the metal wire;
- plastic stretching of the metal wire by means of at least two rotating shafts, wherein the distance or tension between the rotating shafts can be adjusted, thus obtaining a stretched metal wire;
- measuring the diameter of the stretched metal wire;
- controlling the distance or tension between the rotating shafts in steps based on the diameter of the metal wire and the diameter of the stretched metal wire;
- driving of the stretched metal wire; and
- stress relief of the stretched metal wire.

[0080] In a particular embodiment, the present invention also provides a stretching device comprising at least:

- an unrolling device for unrolling the metal wire;
- at least one measurement device for measuring the diameter of the metal wire;
- a stretching station comprising at least two rotating shafts, wherein the distance or tension between the rotating shafts is adjustable, wherein incoming metal wire is stretched to obtain a stretched metal wire;
- at least one measuring device for measuring the diameter of the stretched metal wire;
- control of the distance or tension between the at least two rotating shafts from the measurement device for the metal wire and the stretched metal wire; and
- a drawing plate for driving the metal wire.

Examples

[0081] Fig. 1 shows a diagrammatic depiction of a specific embodiment of the method described here for plastic stretching of a steel wire.

[0082] The method comprises in a first step (101) pro-

viding a hot-rolled steel wire (rolled wire) and continuous unwinding of the rolled wire. The wire is transported through the various steps of the method at a speed of around 7 m/s. In a first measurement step (102), the diameter of the wire is measured optically. The rolled wire is then stretched plastically (103) by guiding the metal wire over two or more rotating shafts which exert a force on the metal wire. As a result, the wire is elongated by between 5% and 20%. The distance between the rotating shafts is controlled by motors, allowing adjustment of the force on the metal wire. In a subsequent step (104), the diameter of the stretched wire is measured optically. The measurements in steps (102) and (104) take place at a frequency of around 1200 measurements per second, which equates to approximately one measurement every 6 mm. Based on the measured diameters, the force exerted by the rotating shafts in step (103) is controlled (black arrows) to give a uniform wire thickness. The measurements in steps (102) and (104) can take place at a frequency of around 4000 measurements per second, even up to 10000 or more measurements per second.

[0083] The process is driven by means of a drive (105) which uses a drawing plate. In a further step (106), the wire undergoes a short elongation (approximately 0.5%). In a final step (107), the wire is rolled up.

[0084] This method allows the spread of wire diameters to be kept smaller than with standard methods. In this way, an associated elongation of 2 to 3% can be obtained, wherein the required minimum diameter of the wire remains guaranteed. This means a significant saving in material.

Claims

1. Method for plastic stretching of metal wire, comprising:

- (a) providing a metal wire;
- (b) measuring the diameter of the metal wire;
- (c) plastic stretching of the metal wire provided in step (a) and measured in step (b) by means of at least two rotating shafts, whereby the distance or tension between the rotating shafts can be adjusted, thus obtaining a stretched metal wire;
- (d) measuring the diameter of the stretched metal wire;
- (e) controlling the distance or tension between the rotating shafts in step (c) based on the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d).

2. Method according to Claim 1, wherein steps (a) to (e) take place continuously.

3. Method according to Claim 2, wherein the metal wire is transported continuously at a speed of between 50 m/min to around 1000 m/min.
4. Method according to any one of Claims 1 to 3, wherein the stretched metal wire is driven by a drawing device positioned after the stretching device performing step (c). 5
5. Method according to any one of Claims 1 to 4, wherein the metal wire provided in step (a) is a hot-rolled metal wire. 10
6. Method according to any one of Claims 1 to 5, wherein the metal wire provided in step (a) is a smooth metal wire, preferably a smooth hot-rolled metal wire. 15
7. Method according to any one of Claims 1 to 5, wherein the metal wire provided in step (a) is a profiled metal wire, preferably a profiled hot-rolled metal wire. 20
8. Method according to any one of Claims 1 to 7, wherein the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d) are measured using optical measurements. 25
9. Method according to Claim 8, wherein the optical measurement of the diameter is derived from the distance between the edges of the metal wire or the distance between the profiles of the metal wire. 30
10. Method according to any one of Claims 1 to 7, wherein the diameter of the metal wire measured in step (b) and the diameter of the stretched metal wire measured in step (d) are measured by measurement of the speed of the metal wire in step (b) and the speed of the stretched metal wire in step (d). 35
11. Method according to any one of Claims 1 to 10, wherein the plastic stretching in step (c) causes an elongation of the metal wire of at least 1%. 40
12. Method according to any one of Claims 1 to 11, wherein the plastic stretching in step (c) reduces the variation in diameter of the stretched metal wire to maximum 1%. 45
13. Method according to any one of Claims 1 to 12, wherein the method comprises the additional steps selected from: 50
 - unrolling of the metal wire;
 - stripping of the metal wire;
 - coating of the metal wire and/or the stretched metal wire;
 - application of a profile to the metal wire or stretched metal wire;
- cooling of the stretched metal wire;
- passivation of the stretched metal wire;
- stress relief of the stretched metal wire; and/or
- winding of the stretched metal wire.
14. Method according to any one of Claims 1 to 13, wherein the method comprises unrolling the metal wire at the starting position and rolling up the metal wire at the end position, and wherein between the unrolling and rolling up, the metal wire undergoes at least one of the following steps:
 - measuring the diameter of the metal wire;
 - plastic stretching of the metal wire by means of at least two rotating shafts, wherein the distance or tension between the rotating shafts can be adjusted, thus obtaining a stretched metal wire;
 - measuring the diameter of the stretched metal wire;
 - controlling the distance or tension between the rotating shafts in steps based on the diameter of the metal wire and the diameter of the stretched metal wire;
 - driving of the stretched metal wire; and
 - stress relief of the stretched metal wire.
15. Stretching device comprising at least:
 - an unrolling device for unrolling the metal wire;
 - at least one measurement device for measuring the diameter of the metal wire;
 - a stretching station comprising at least two rotating shafts, wherein the distance or tension between the rotating shafts is adjustable, wherein incoming metal wire is stretched to obtain a stretched metal wire;
 - at least one measuring device for measuring the diameter of the stretched metal wire;
 - control of the distance or tension between the at least two rotating shafts from the measurement device for the metal wire and the stretched metal wire; and
 - a drawing plate for driving the metal wire.

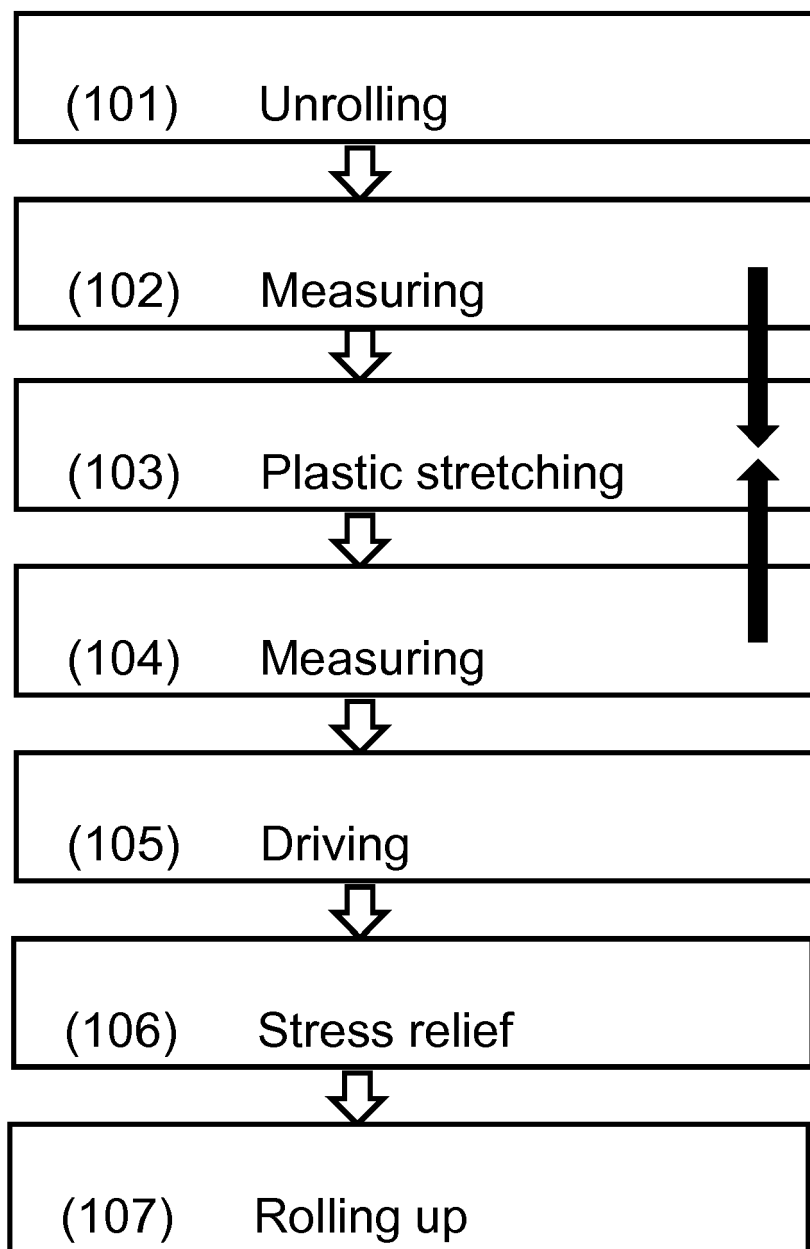


Fig. 1



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