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Scheucher

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[54] **PROCESS FOR MEASURING THE MODULUS OF ELASTICITY**

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[52] **U.S. Cl.** **73/95.5**

[51] **Int. Cl.** **G01n 3/08**

[58] **Field of Search** 73/95.5, 160, 89

[56] **References Cited**

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[57] **ABSTRACT**

Continuously measuring the yield point and/or modulus of elasticity of a continuously moving wire or strip by subjecting it to a predetermined tensile strain and continuously measuring the tensile stress required for achieving that predetermined strain. The quality of the wire or strip may be controlled to maintain given characteristics by varying upstream conditions, such as annealing temperature, in response to variations in the tensile strain.

6 Claims, 6 Drawing Figures

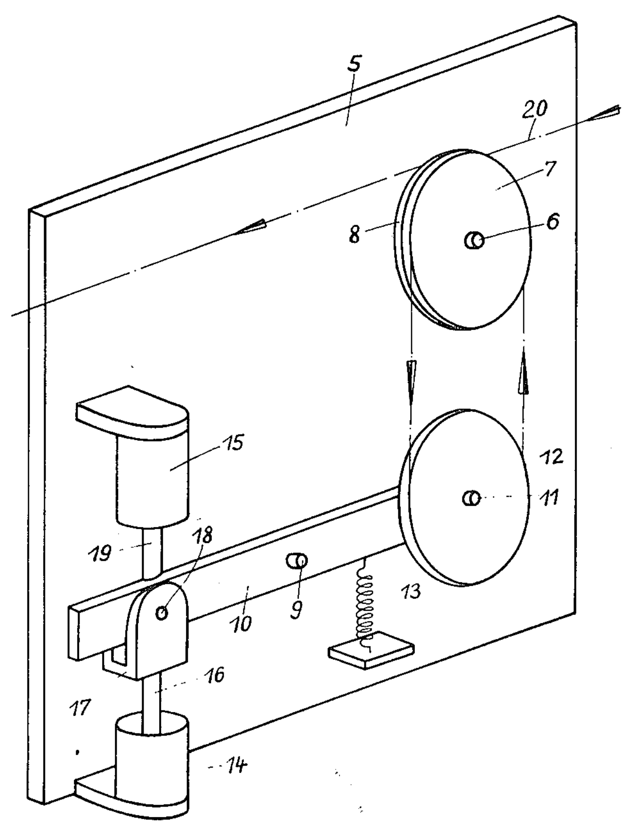


FIG.1

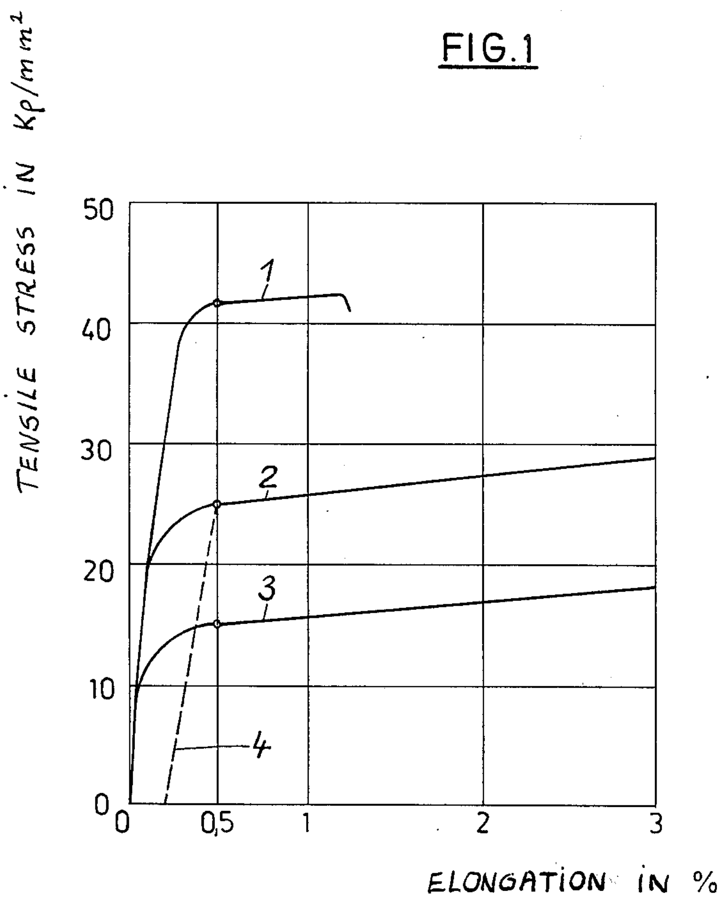

TENSILE STRESS IN Kp/mm²
50
40
30
20
10
0
0
0,5
1
2
3
1
2
3
4
ELONGATION IN %

FIG. 2

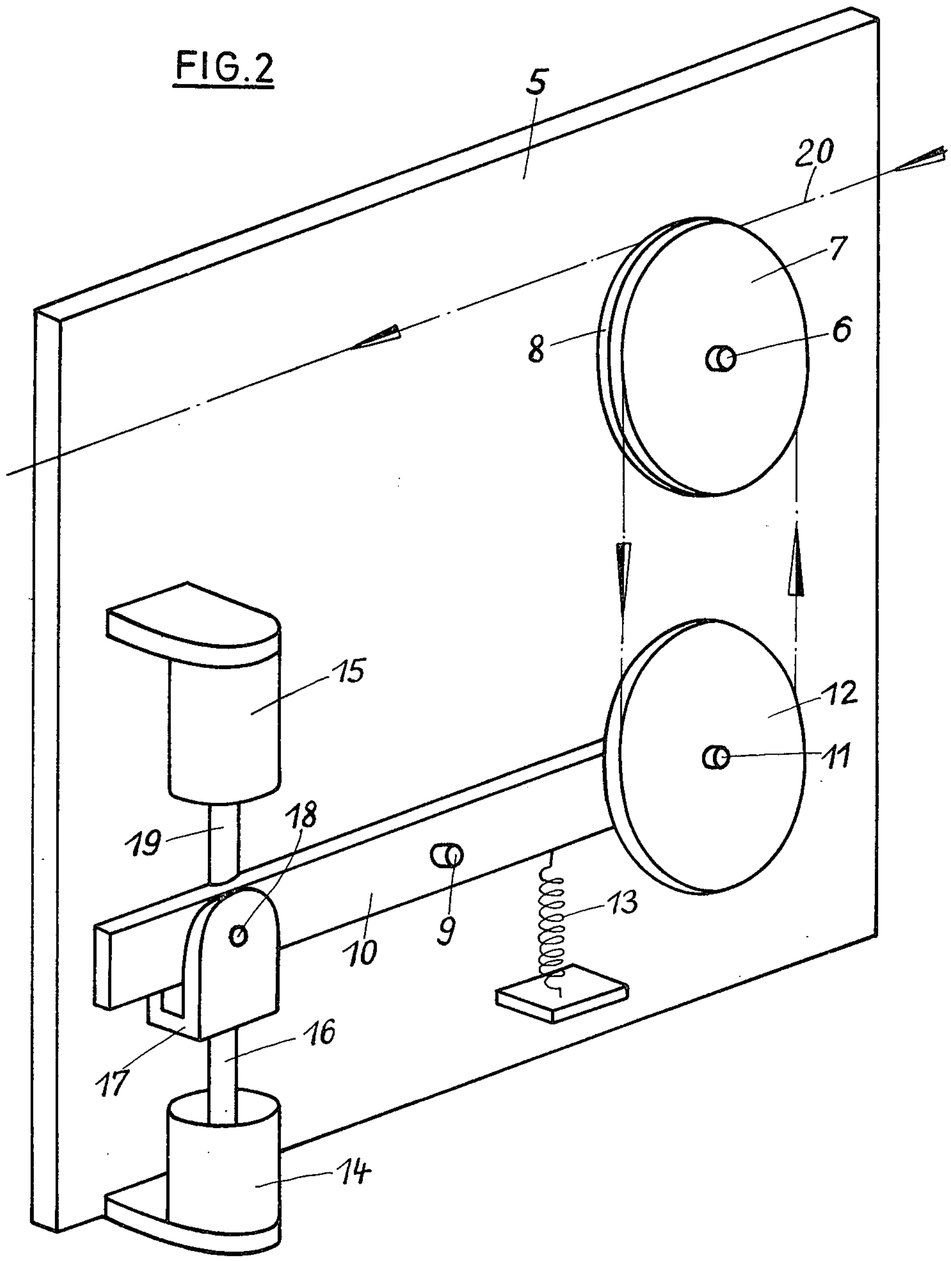


FIG.3

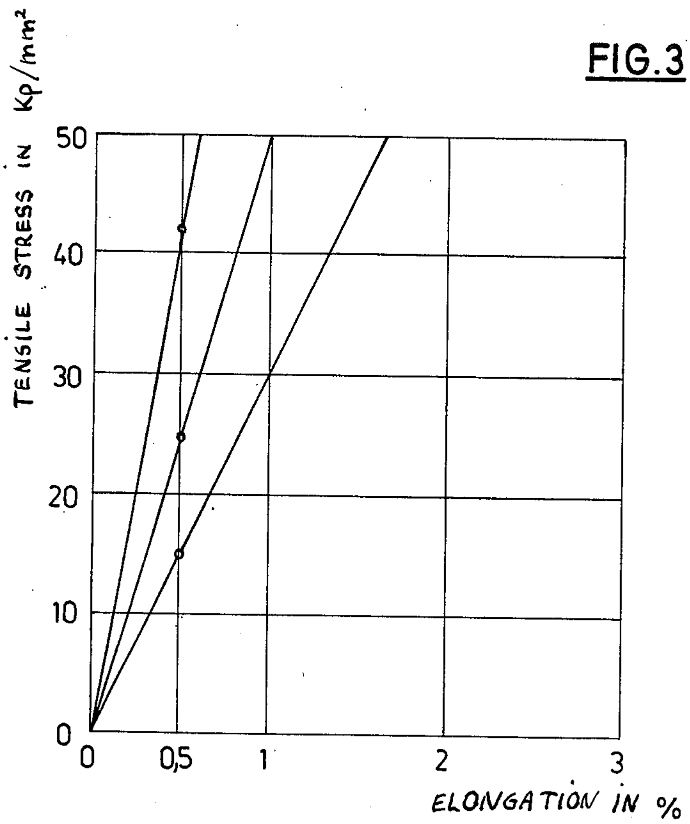
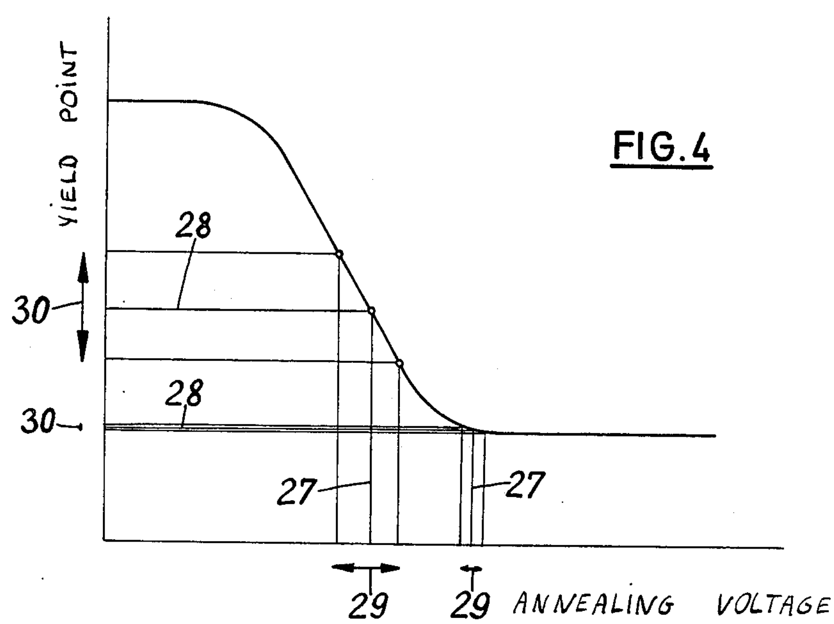

TENSILE STRESS IN Kp/mm²
50
40
30
20
10
0
0
0,5
1
2
3
ELONGATION IN %

FIG.4


YIELD POINT
28
30
28
30
27
27
29
29
ANNEALING VOLTAGE

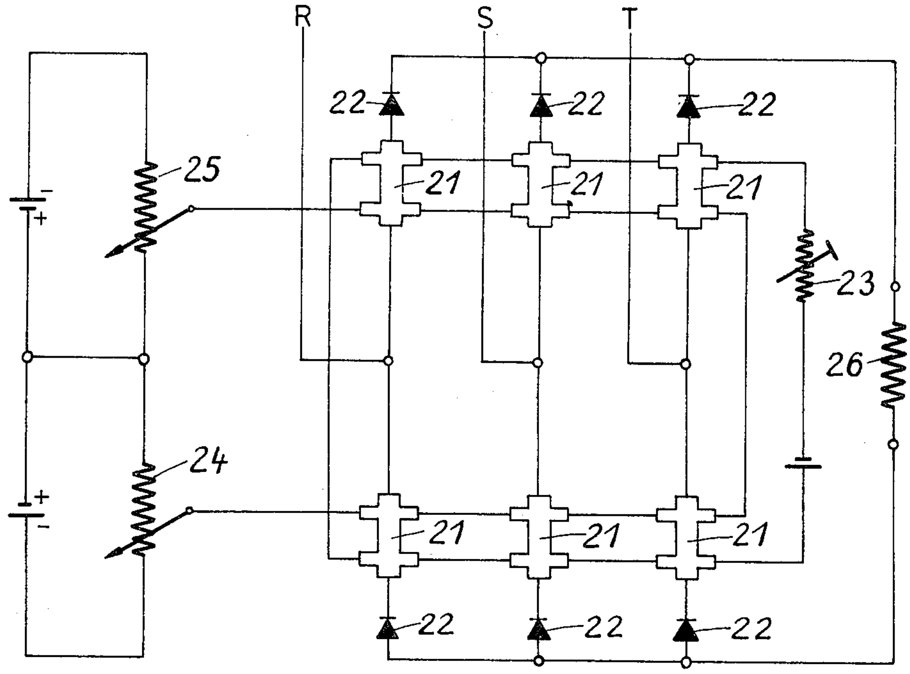


FIG.5

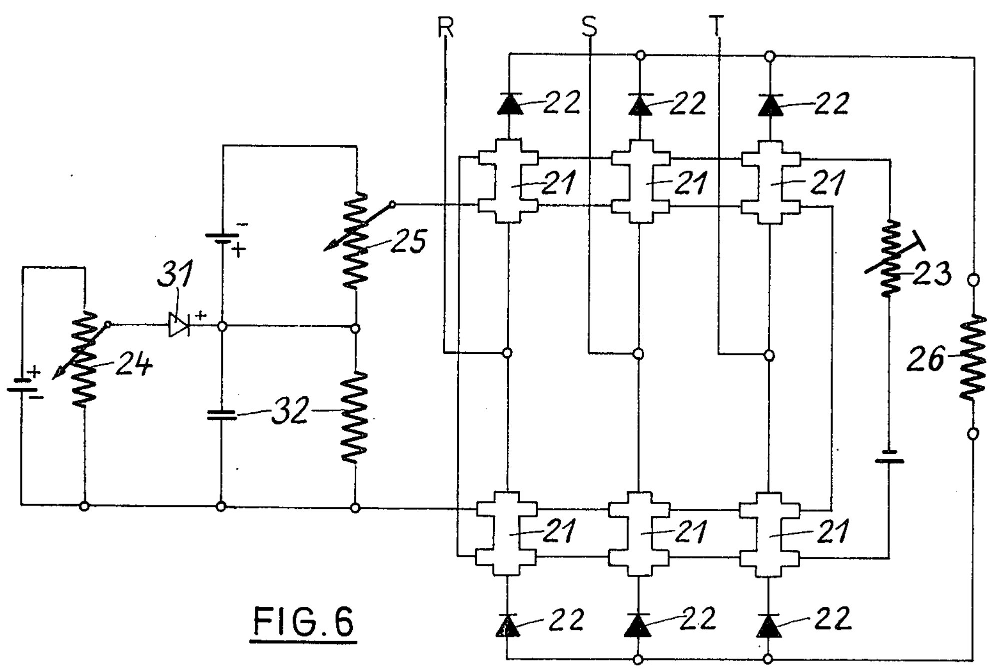


FIG.6

PROCESS FOR MEASURING THE MODULUS OF ELASTICITY

BACKGROUND OF THE INVENTION

The invention relates to a process for the continuous measurement of the yield point and/or of the modulus of elasticity of wires, strips or the like, of metallic or non-metallic materials, which are being moved in their longitudinal direction.

In the manufacture of wires of copper or other metallic materials by cold-drawing there is a great deformation below the recrystallisation temperature, giving rise to a great hardening through crystal defects of all kinds, as a result of which the breaking strength and the yield point rise but the elongation at break greatly declines. Since generally a soft or semi-hard wire is desired, this greatly hardened wire must subsequently be subjected to a recrystallisation annealing which is also necessary if very thin wires are to be produced in a second drawing process. This intermediate annealing in the case of very thin wires prevents the occurrence of pronounced drawing structure.

The annealing of the wires can be effected, for example, in dome furnaces. However, a more economical method is the continuous process in which the wires pass through heated tubes the temperature of which is suitably adapted to the recrystallisation behavior of the material to be annealed. Annealing devices in which a heating current is directly fed via several contact rollers to the wire to be annealed, so that heating takes place with minimum heat losses, are even more economical. A particular advantage of these electrical annealing devices is that they can without difficulty be so designed that their working speed corresponds to that of the drawing process, and the drawing and annealing devices can be directly coupled to one another.

It is known that the recrystallisation properties of metallic materials depend on their composition and their pre-treatment. Particularly in the case of pure metals, for example in the case of electrolytic copper used for electro-technical purposes, residual impurities play a decisive role. Here foreign materials can cause increases in the recrystallisation temperature of several 100° even if present only in amounts of the order of magnitude of 0.01 percent. This results in considerable practical difficulties in the annealing of wires because, for example, the strength properties measured on the finished product fluctuate to a degree which frequently is no longer acceptable. The manufacture of wires or strips which are to display semi-hard material properties with the requisite reliability proves particularly difficult. The slightest temperature deviations or changes in the composition of the material here cause unacceptable errors, because of the steepness of the recrystallisation curve.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a process for the continuous measurement of the yield point and/or of the modulus of elasticity of wires or strips of metallic or non-metallic materials, characterised in that the wire or strip is stretched by predetermined tensile strain while being advanced along a feed direction, and the tensile force to attain this predetermined strain is measured continuously.

According to a second aspect of the invention a process for continuously annealing a moving wire or strip is provided. This process includes passing a current along a run of wire or strip between two guides, stretching the wire or strip to achieve a predetermined tensile strain, measuring the tension required to achieve the predetermined strain and controlling the annealing current in dependence upon the tension measured.

A third aspect of the invention provides apparatus for continuously measuring the yield point and/or the modulus of elasticity of the wire or strip. The apparatus includes a device for feeding a wire or strip longitudinally with a given rate of advance, a further device for feeding the wire or strip delivered from the first feeding device with a rate of advance, greater than that of the first feeding device, by a known amount, and a device for measuring the applied tension in the run of wire or strip passing between the first and second feeding devices.

Using the process according to the first aspect of the invention, the yield point or the modulus of elasticity of the wire, strip or the like can be continuously monitored in a simple manner. From the measured data it is possible to derive a signal for the automatic balancing-out of deviations from the intended value. As a result it is possible to obtain wires or strips which display constant mechanical properties since, for example, the elongation at break and tensile strength for a given material bear a unique relationship to the yield point.

In a preferred form of the apparatus according to the invention, the two feeding devices include two concentric rollers rigidly connected to one another and having diameters which differ by a fraction equivalent to the pre-determined percentage elongation (tensile strain). The wire or strip is stretched by this pre-determined strain between passing over each of the two rollers which are rigidly connected to one another. The tensile stress which thus arises in the wire or strip is a measure of the yield point of the wire, strip or the like. It can be continuously measured with the aid of a third roller mounted on one arm of a spring-biased two-arm lever the other arm of which is connected on one side to a damping device and on the other side to a length determining device. The damping device prevents sudden major pivoting movements of the lever which could falsify the measurement. The length-determining device measures the angular displacement of the lever from its zero position, for example its horizontal position where the two arms of the lever are parallel. Since the spring counteracts the tensile force in the stretched run of the wire in such a way that the lever is in the equilibrium state, the particular angular position of the lever is a measure of the yield point of the wire or strip. At the same time the horizontal position of the lever can correspond to a pre-determined intended value of the yield point.

This principle of measurement is applicable wherever information is desired on the yield point or the modulus of elasticity. This principle of measurement therefore, can also be used advantageously in the processing of plastics, if the yield point or the modulus of elasticity depend on the parameters of the manufacturing process and monitoring or control is desired.

The measuring device according to the invention can follow a manufacturing device or further processing device for wires or strips and can possess a regulating device which keeps the yield point and/or the modulus of elasticity to a pre-determined intended value. This regulating device can include transducers or thyristors.

If the wires or strips are to be subjected to a recrystallisation annealing, the measuring device according to the invention can be located between the corresponding annealing device and a wind-up coil, and the annealing device can be controllable by the length-determining device. If for example the yield point of the annealed wire as determined by the measuring device is too high, that is to say the wire is still too hard, the length-determining device of the regulating device automatically provides an appropriate signal which causes the annealing device to heat the wire more strongly so that the yield point is lowered and regulated to the predetermined intended value. Equally, the yield point is regulated to the predetermined intended value if it is too low.

It is possible to use any desired length-determining device. Thus, for example, an inductive length-determining device or a length-determining device consisting of a photocell arrangement can be provided.

If the apparatus according to the invention is employed with an annealing device in which the annealing of the wire, strip or the like is effected by a current which is passed directly through the wire or strip, the annealing voltage continuously fluctuates periodically about a mean value for automatically attaining the lowest possible yield point, and a regulating device is provided which adjusts the mean value of the annealing voltage as a function of a predetermined minimum amplitude of the fluctuation in the yield point. In this way it is possible to produce a soft wire for coiling purposes. Here again, the regulating device may comprise transducers or thyristors.

A great advantage of the apparatus is the possibility that during start-up, while the annealing device is being run up, wires of the desired strength characteristics can be obtained even before the working speed has achieved its full value. If provision is made for the annealing voltage to be regulated sufficiently rapidly, the entire installation can in a short time be brought to full speed from stand still, while the annealing voltage corresponding to the particular speed is adjusted by the regulating device. Since the wire or strip attains the properties described above even during starting-up of the installation, a corresponding saving in material wastage is realised.

Great advantages result if the measuring apparatus is located within the annealing zone so that the measurement is carried out at the annealing temperature where the strength properties again depend on the degree of recrystallisation. Though this measurement will not give the room temperature value, which is generally of interest, the measurement within the annealing zone bears a unique relationship therewith. In addition to the simplicity of the arrangement, it can here be of advantage that the material undergoes partial recrystallisation after passage through the measuring device.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the present invention may more readily be understood the following description is given, merely by way of example, reference being made to the accompanying drawings.

FIG. 1 shows the stress-elongation characteristics of copper wires of varying hardness.

FIG. 2 schematically shows a measuring device according to the invention.

FIG. 3 shows a stress-elongation diagram of several materials with different modulus of elasticity.

FIG. 4 shows a curve indicating the yield point of a material as a function of the annealing tension.

FIG. 5 shows a circuit of a regulating device in accordance with the present invention.

FIG. 6 shows a circuit of a further regulating device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 represents three curves **1**, **2** and **3** for hard, semi-hard and soft copper wire. If, after delivery, from an annealing device, this copper wire is stretched continuously by, for example, 0.5 percent, the tensile stress to be applied for this purpose according to FIG. **1** depends unambiguously on the yield point. The corresponding tensile stress values for these wires are between 42.25 and 15 kp/mm^2 according to FIG. **1**. The broken straight line **4** in FIG. **1** shows that when the tensile stress drops from 25 kp/mm^2 to zero a permanent elongation of about 0.2 percent remains.

FIG. 2 shows a plate **5** having two rollers **7** and **8**, located concentrically to one another and rigidly connected to one another, rotatably carried by means of an axle **6**. Further, a two-arm lever **10** is pivotally carried on the plate **5** by means of an axle **9**. The right hand arm of the lever **10** carries an axle **11** which rotatably supports a roller **12**. A tension spring **13** is also operatively connected on the right hand arm of the lever **10**. A damping device **14** and a length-determining device **15** are mounted on the plate **5** in the region of the left hand arm of the lever **10**. A piston rod **16** of the damping device **14** possesses a double prong **17** which loosely surrounds the left-hand arm of the lever **10** and is articulated thereto by means of a pin **18**. A probe **19** of the length-determining device **15** rests on the left hand arm of the lever **10** in such a way that it follows every swivelling movement of this arm of the lever **10**. The damping device **14** can be a fluid damping device.

A wire **20**, which can come from an annealing device (not shown) beyond the right of FIG. **2**, is successively passed over the rollers **7**, **12** and **8** and is coiled up on a coiling-up bobbin (not shown) located next to the plate **5**. The roller **8** is 0.5 percent larger in diameter than the roller **7** and thus the wire **20** is stretched by 0.5 percent in its path between the two rollers **7** and **8**. This elongation is composed of an elastic and a plastic component. The peripheries of the rollers **7**, **8** and **12** are so constructed that undesirable slipping of the wire **20** on these rollers is reliably prevented. When the wire **20** comes off the roller **8** it is again free of tension. The broken straight line **4** in FIG. **1** depicts the relaxation curve of the wire **20** coiled up on the coiling up bobbin and shows a permanent set which is clearly always less than 0.5 percent and does not in practice interfere with the process.

It will be assumed that the axle **11** is held stationary relative to the axle **6** and is at such distance therefrom that the lever **10** is in a horizontal middle position. The two rollers **7** and **8** which are rigidly connected to one another rotate in an anti-clockwise direction at the same angular velocity when the wire **20** moves. Since, on n revolutions of both rollers **7** and **8**, a length $n.D.\pi$ passes around the roller **7** and the length $n.D.(1 + 0.5\%)\pi$ passes around the roller **8**, the wire **20** is stretched by 0.5 percent $n.D.\pi$ between the two rollers **7** and **8.** In the course of this the axle **11** of the roller **12** is pulled upwards by a tensile force directly proportional to the tensile stress acting in the wire. With the axle **11** freely movable relative to the axle **6** this tensile force can now be so compensated by the force of the spring **13,** that for a predetermined yield point the lever **10** is in its horizontal middle position.

If now, for any reason, the material of the wire passing through the measuring device become harder, the yield point is higher and a greater tensile force is necessary to achieve the elongation of 0.5 percent. The spring **13** will therefore stretch until its increased tensile force corresponds to the tensile force which effects an elongation of 0.5 percent. At the same time, the double-armed lever **10** executes a swivelling movement about its axis **9,** in an anti-clockwise direction.

If the material of the wire **20** passing through the measuring device becomes softer, the yield point is lower and a lower tensile force in the wire **20** is necessary to achieve the elongation of 0.5 percent. Since, however, the tension spring **13** exerts a greater force in the horizontal middle position of the lever **10** than is necessary to stretch the wire **20** by 0.5 percent, the wire **20** is stretched underneath the two rollers **7,8** by this greater tensile force of the tension spring **13** until the tension spring **13** exerts a tensile stress corresponding to 0.5 percent elongation. At the same time the lever **10** thus executes a swivelling movement about its axis **9,** in the clockwise direction as viewed in FIG. **2.**

Abrupt swivelling movements of the lever **10** are prevented by the damping device **14.** The swivelling movements of the lever **10** thus effect the movements of the probe **19** of the length-determining device **15** which movements are converted into signals for the automatic control of the annealing device. If the wire **20** passing through the measuring device is too hard the working temperature at the annealing device is adjusted as a result of the movement of the probe **19,** so as to heat the wire more strongly in order again to achieve the predetermined yield point and hence the desired character of the material. If the wire **20** passing through the measuring device is too soft the annealing device is re-regulated by the corresponding movement of the probe **19** of the length-determining device **15** so that it heats the wire **20** less strongly to allow the yield point to revert to the predetermined value to allow the desired material character to be achieved.

FIG. **5** shows a circuit diagram of a regulating device which is capable of holding the yielding point and/or the modulus of elasticity to a predetermined intended value. This regulating device comprises electromechanical movement transducers **21** silicon rectifiers **22,** a regulator **23** for the pre-magnetisation, a device **24** controlled by the probe **19** of the length-determining device for recording the actual value, and a device **25** for setting the intended value. Element **26** denotes the annealing zone of the wire **20.**

FIG. **3** shows a tension-elongation characteristic of materials which have differing moduli of elasticity, but do not have a pronounced elastic limit. The process according to the invention and the measuring device illustrated in FIG. **2** can also be used with these materials.

The possibility also exists of automatically achieving the lowest possible yield point for a given material quality. This may, for example, be required in the manufacture of coil-winding wires. For this purpose, an annealing voltage applied to the wire **20** continuously and periodically oscillates about a mean value. In FIG. **4,** the yield point of the soft wire is plotted against the annealing voltage and the mean value of the annealing voltage which is marked **27** and corresponds to a mean value **28** of the yield point. The amplitude **29** of the fluctuation of the annealing voltage corresponds to an amplitude **30** of the fluctuation of the yield point. This amplitude **30** of the fluctuation of the yield point is determined by a measuring technique. As long as this amplitude **30** has not yet diminished to a predetermined minimum value, the mean value **27** of the annealing voltage is increased to shift the working region along the characteristic towards the right in FIG. **4.** On increasing the mean value **27** of the annealing voltage in this way, both the corresponding mean value **28** of the yield point and the amplitude **30** of the fluctuation of the yield point become progressively less. As soon as the amplitude **30** of the fluctuation of the yield point has reached the predetermined minimum value, the mean value **27** of the annealing voltage is prevented from rising further. The yield point of the annealed material then fluctuates about a value near the achievable optimum. The regulating system itself is so designed that the extent of fluctuation of the yield point and its mean deviation from the optimum are so small as no longer to be objectionable.

FIG. **6** shows a circuit of a suitable regulating device provided for this purpose. This regulating device includes transducers **21,** silicon rectifiers **22,** a regulator **23** for the pre-magnetisation, a device **24** for determining the actual value, a device **25** for setting the intended value, a rectifier **31** and a band-pass filter **32.** The annealing zone of the wire **20** to be annealed is again marked **26.** The device **24** for determining the actual value, limits a signal which in the present case is a direct voltage with superposed alternating voltage. This signal is first rectified by the rectifier **31** and then the resulting direct voltage, which is proportional to the alternating voltage component of the basic signal, is compared with the set intended value. In this way it is always possible to automatically maintain an optimum state of softness of the annealed wire in accordance with the FIG. **4** characteristic.

The measuring device illustrated in FIG. **2** may be disposed in the annealing device, in which case the annealing voltage is applied to the wire as it passes through the measuring device and hence the wire is heated by the current which flows through it. In addition to the simplicity of this arrangement, there is the further advantage that a part of the recrystallisation of the wire takes place only after passage through the measuring device and it is then possible to avoid the above-mentioned loss in the elongation at break, which is less than 0.5 percent (see straight line **4** in FIG. **1**).

We claim:

1. In a process for the continuous measurement of the modulus of elasticity of an elongated body of metallic or non-metallic material whose yield point corresponds approximately to a predetermined percentage elongation, comprising the steps of: advancing the body along a feed path; stretching the body for attaining a constant percentage elongation while it is being advanced; and continuously measuring the tensile force to attain this elongation, the improvement wherein said step of stretching is carried out to effect such predetermined percentage elongation such that the corresponding tensile force is nearly the yield point of the material.

2. A method as defined in claim **1** wherein said step of stretching is carried out by engaging the elongated bodies at the peripheries of two rollers of different diameters which are rigidly connected together and are concentrically disposed on a drive shaft, the diameters of the two rollers differing from each other by a constant percentage by which the elongated body is stretched, and which corresponds to such predetermined percentage elongation so that the corresponding tensile force is nearly the yield point of the material, and passing the body over a third roller as it travels between said two rollers, said third roller being spaced a distance from said two rollers and biased for movement in a direction tending to increase the tensile stress in the body passing between said two rollers said third roller being rotatably supported by a spring-biased pivotally mounted lever.

3. A method as defined in claim **2,** wherein said lever is a two-arm lever having first and second arms, said first arm carrying said third roller, and damping means being connected to one side of the said second arm, and said step of measuring is performed by length-determining means connected to the other side of said second arm for measuring the tensile force.

4. A method as defined in claim **3,** wherein said length-determining means is an inductive length-determining means.

5. A method as defined in claim **3,** wherein said length-determining means includes a photocell device.

6. A method as defined in claim **3,** wherein said step of measuring includes keeping the yield point and the modulus of elasticity at a predetermined intended value.

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