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[54] **CONTINUOUS RESISTANCE ANNEALING METHOD FOR WIRES**

[75] Inventors: **Ahti A. Kosonen; Seppo A. Nieminen,** both of Pori, Finland

[73] Assignee: **Outokumpu Oy,** Outokumpu, Finland

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[52] **U.S. Cl.**................**219/155,** 148/13 R, 142/13.2

[51] **Int. Cl.**...**C21d 9/62**

[58] **Field of Search**............219/155; 148/13 R, 13.2

[56] **References Cited**

UNITED STATES PATENTS

2,589,283	3/1952	O'Grady	219/155
2,726,971	12/1955	O'Grady	219/155
3,335,260	8/1967	Ferschl	219/155
1,635,443	7/1927	Smith et al.	148/13 R
1,911,023	5/1933	Kelley	148/13.2 X

Primary Examiner—C. L. Albritton
Attorney—Albert M. Parker

[57] **ABSTRACT**

A wire running through contact wheels is resistance heated by a current set to heat the wire in a first step to a relatively low temperature which has been determined experimentally and which is dependent upon, e.g., the drawing rate, the protective gas used, cooling, the thickness of the wire, the length of the annealing distances, and the solidus temperature of the wire to create a controlled number of crystal nuclei in the wire and then the actual annealing is effected in a second step by a current heating the wire to a high temperature to recrystallize the wire completely.

6 Claims, 2 Drawing Figures

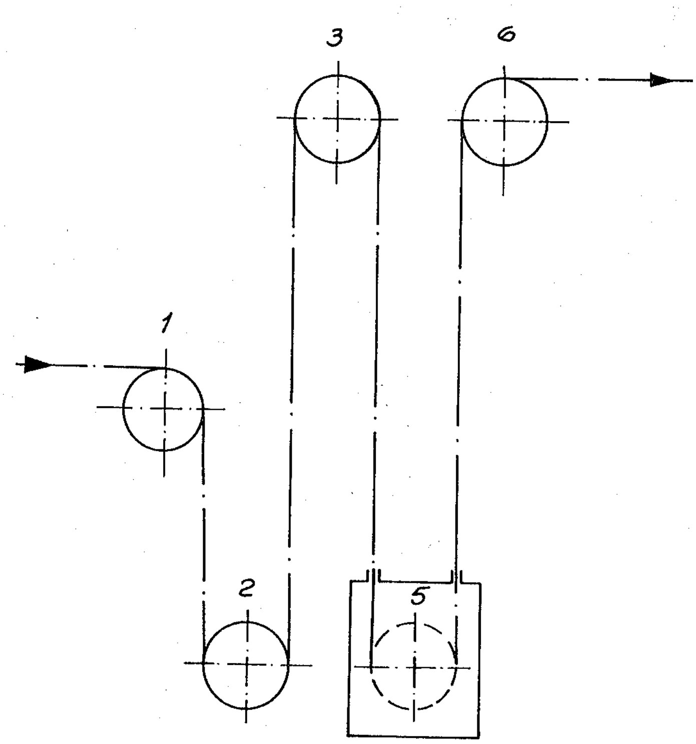
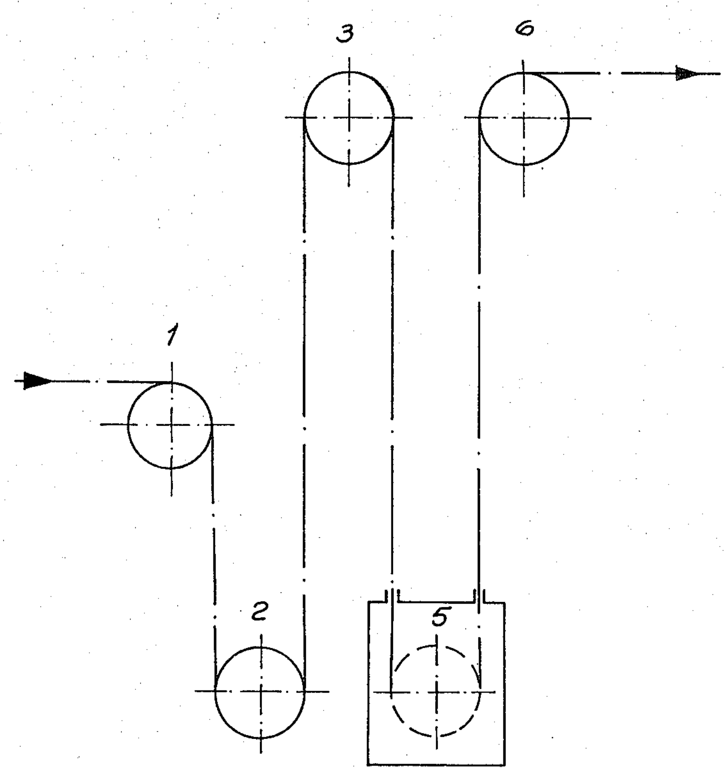
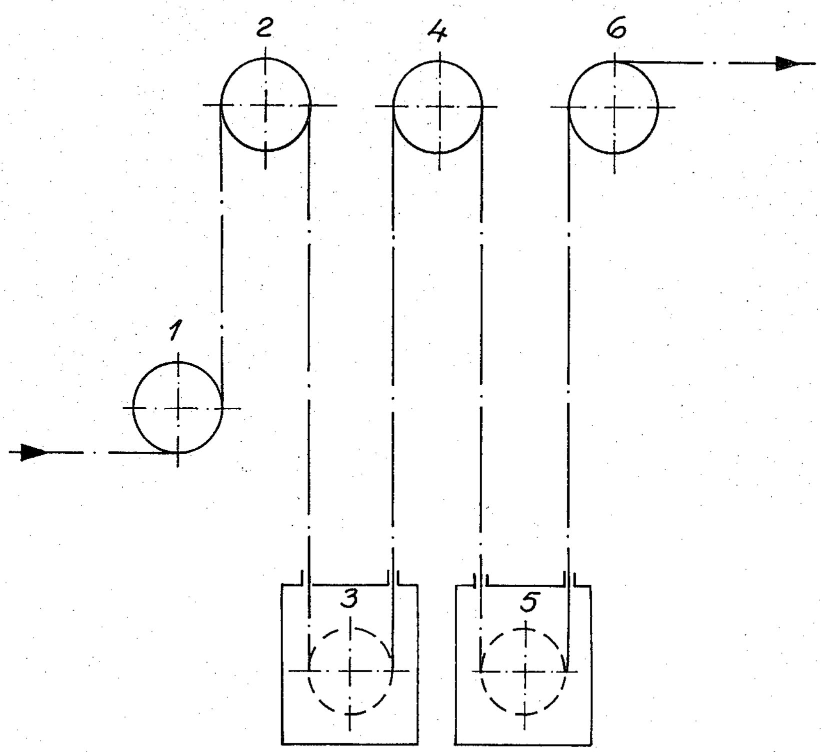


Fig. 1



AHTI A. KOSONEN
and
SEPPO A. NIEMINEN
INVENTORS.
BY Albert M. Parker
ATTORNEY.

Fig. 2



and AHTI A. KOSONEN
SEPPO A. NIEMINEN
INVENTORS.
BY Albert M. Parker
ATTORNEY.

CONTINUOUS RESISTANCE ANNEALING METHOD FOR WIRES

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The invention relates to the field of continuous resistance annealing of wires.

2. DESCRIPTION OF THE PRIOR ART

Several annealing methods for wires are used in practice. In principle, they can be divided into two categories:

1. Batch annealing or tempering methods in which coiled or spooled wires are annealed in different furnaces such as bell, salt bath, roller grate, muffel, etc. The transferring of heat takes place by radiation and/or convection. 2. Annealing by continuous methods in which wires are conveyed through a pipe heated from the outside or in which wires are heated directly either inductively or resistively.

The batch annealing or tempering methods are characterized by long heating periods as it takes a long time to obtain an even temperature in massive spools. A further disadvantage is the possible sticking together of the loops of wire because of the long annealing period and the high temperature. In addition, the degree of purity of the wires may remain unsatisfactory after the annealing because of, for example, the wire-drawing greases evaporating from the wires, or the vaporization of components present in the wires themselves, such as zinc. On the other hand, the structural properties of the material can be regulated with relative facility and within a wide range because of the long annealing period and the relatively precise control of the temperature.

When annealing is carried out by continuous methods in a through-type furnace, the annealing capacity remains low because of the slow movement of the wires, which is the reason why the method is expensive. If the annealing capacity is increased either by lengthening the furnace or by increasing the number of wires to be drawn through it, the furnace becomes very impractical structurally. In the inductive method the annealing level remains very low; therefore, it is very seldom used for wires and never for thin wires. Among the continuous annealing methods, resistance annealing is gaining ground because it is very rapid and because the required annealing unit is small compared with the other furnace types mentioned above. The method is used especially in connection with wire-drawing machines, in which case the wire hardened during the drawing process is immediately conducted into the annealing unit. It can, however, be noted that the resistance annealing method has the disadvantage that, owing to the very rapid annealing which takes place in a fraction of a second, the qualities required of annealed wire cannot always be obtained.

German Pat. No. 1,186,223 introduces a resistance annealing method in which wire is annealed with current impulses, and its purpose is to eliminate the unevenness of wire due to, for example, a changing drawing rate. When current impulses are used for the annealing, some parts of the wire will be annealed twice, but it will not cause any harm as no noteworthy crystal growth takes place in such a rapid annealing. Nevertheless, the properties of the wire thus annealed are, on the average, similar to those of wire that has undergone a normal resistance annealing process. Attempts have been made to increase the crystal size by resistance annealing or tempering also by first raising the temperature relatively fast and then stopping the rising of the temperature by directing the wire into cooling liquid. In spite of the fact that the wire may run over several contact wheels the purpose is to create conditions for crystal growth but, because of its slowness, either the annealing distance becomes impractically long or the gained advantage remains quite insignificant.

Conventional resistance annealing is used mostly in annealing copper, and the method is well suited for this purpose since the softening occurs at relatively low temperatures and usually the crystal size grows easily because there are no alloyers or impurities that would obstruct the growth of the crystals. Therefore, the desired properties can be obtained with copper fairly easily, but when large crystal sizes are desired (the crystal-growing method being the only known method by which they can be obtained) the outcome will easily be an uneven structure, which results in a variation of properties in the same wire. However, usually it is not possible to obtain large crystal sizes for metals by the known resistance annealing methods.

SUMMARY OF THE INVENTION

According to the invention the wire is first heated to a low temperature experimentally determined to create a controlled member of crystal nuclei and then the wire is heated to a high temperature to crystallize the metal wire completely.

In resistance annealing the softening of the metal occurs through recrystallization. The recrystallization comprises three phases: recovery, primary recrystallization, and crystal growth. Primary recrystallization takes place so that crystal nuclei are born in the treated structure and they grow into crystals.

Crystal growth takes place so that some of the crystals formed in primary recrystallization grow larger at the expense of other crystals. The properties of soft wire depend upon the crystal size so that when the crystal size enlarges, the strength and hardness decrease and the tenacity, (or, more accurately in the language of metallury, tensility), increases. Crystal size is regulated by the annealing temperature so that the desired properties are obtained. Due to the short annealing period in the resistance annealing process no noteworthy crystal growth will occur during it. In this case the crystal size of resistance annealed wire remains in general essentially the same as it has been after the primary recrystallization or, in other words, the number of crystals is the same as the number of formed crystal nuclei.

The nucleation rate is strongly dependent upon the temperature so that when the temperature rises the number of formed nuclei increases. Consequently, the crystal size created in resistance annealing will be smaller the higher the temperature at which the nucleation occurs. In normal resistance annealing the nucleating takes place at a very high temperature since, owing to the short annealing period, the temperature is raised very rapidly. Therefore, the crystal size of resistance annealed wire tends to remain small. When larger crystal size is desired, the nucleation ought to take place at a temperature as low as possible. This has been made possible by the present invention wherein the annealing is carried out in two phases. In the first phase, a suitable number of crystal nuclei are formed by raising the temperature of the wire so that the desired number of crystal nuclei can be caused to form in the available time. In the second phase, the nuclei born in the previous phase are made to grow so that the structure will be completely recrystallized. This second phase must take place at a temperature lower than the previous phase because of the shortness of the available time. If too few crystal nuclei are formed in the first phase, the result is that a great number of crystal nuclei are formed in the remaining structure to be treated during the second phase and the final result is a mixed crystal structure, and the properties of the wire are not those desired. If too many crystal nuclei are created during the first phase, the result is a small crystal size and, thus, the advantage offered by the nucleating annealing is lost. In practice it takes place so that the annealing process is arranged with the help of three or four contact wheels and using one or more sources of current.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a two-phase annealing method in which the wire is not cooled between the nucleating and the nucleus-growing annealing phases, and

FIG. 2 shows a two-phase annealing method in which the wire is cooled between the nucleating and the nucleus-growing annealing phases.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 the wire runs through contact wheels 1 and 2, where the wire is preheated. During this heating phase, which is in accordance with common practice, the temperature used is so low that the wire will not oxidize and in no case will recrystallization nuclei be formed. This heating is a sort of auxiliary phase and it can be left out. The nucleating annealing according to the invention is carried out between contact wheels 2 and 3. The current used for this annealing is chosen so that, at the end of this phase, the wire contains an exactly suitable number of crystal nuclei. Immediately after this phase, without cooling the wire in between contact wheels 3 and 5, and after this phase the structure is, thus, completely recrystallized. At contact wheel 5 the wire is cooled to such a temperature that the wire will not oxidize after it. The cooling is usually carried out, according to common practice, by water, water emulsion or the like so that contact wheel 5 is in the cooling liquid in question and the wire runs through it. In order to avoid the oxidation of the wire, a protective gas system must usually be fitted between contact wheels 2, 3 and 5. A mild heating with the purpose of drying is carried out between contact wheels 5 and 6 at so low a temperature that no oxidation of the wire will take place, not to speak of crystal growth. The arrangement shown in FIG. 2 deviates from that shown in FIG. 1 in that a cooling is carried out after the nucleating annealing (between contact wheels 2–3) in a similar manner as above at contact wheel 5. A similar preheating is used between contact wheels 3 and 4 as between 1 and 2, which also can be optionally omitted. This arrangement has the advantage that contact wheel 3 is not damaged by oxidation or contamination, which can easily occur in an arrangement according to FIG. 1. The rest of the annealing process takes place in the manner according to FIG. 1.

The method according to the invention has been used successfully for the annealing of wires for wire cloth. In the annealing of the woof for wire cloth (80% Cu, 20% An), the diameter ϕ of the wire being ϕ=0.23 mm and the drawing rate 8.8 m/s, the minimum value obtained for the 0.2-margin by conventional (one-phase) annealing was 16.5 kp/mm^2 and the maximum value for crystal size some 0.008 mm. The term "0.2-margin" is used in accordance with generally adopted European practice to represent such a tensile strength value that a lasting elongation of 0.2 percent results after the removal of stress. This definition is commonly used for materials which lack a sharp limit in their stress-strain curves. By two-phase annealing according to the invention a value of 12.8 kp/mm^2 was obtained for the 0.2-margin and the crystal size was 0.025 mm. The annealing distance in the one-phase experiment was about 800 mm and the nucleating annealing distance in the two-phase annealing was about 1,400 mm. The temperature was about 400°–500°C at the end of the first phase and about 850°–950°C at the end of the second phase.

In the simulation experiments, two current impulses of suitable magnitude were fed to the wire so that the wire was cooled in between. The length of the wire to be annealed in the used unit was about 250 mm, the length of the current impulses 50–300 msec, and the cooling was carried out in a flow of hydrogen. The 0.2-margin obtained with pure nickel wire (ϕ=0.17 mm) was 15.9 kp/mm^2, the temperature of the nucleating annealing being about 300°C and the temperature of the second annealing phase rising to about 1,000°C. If the temperature of the nucleating annealing rose higher or remained lower, the values obtained for the 0.2-margin were 18.1–19.0 kp/mm^2 when the same final annealing was used. In experiments with pure copper wire (ϕ=0.15 mm), the 0.2-margin obtained by a suitable (about 250°C) pre-annealing was 6.9 kp/mm^2, while it was about 7.5 kp/mm^2 otherwise. The temperature of the second annealing phase of the experiment with copper wire was raised to some 950°C. The effect on copper wire was relatively insignificant as could be expected on the basis of what has been discussed above.

The temperatures given above are only directive because they are dependent upon many factors such as drawing rate, protective gas, cooling, thickness of the wire, length of the annealing distances, the solidus temperature of the wire, etc.

The method according to the invention can also be applied to inductive heating, but with the present technical level it is hardly practical because inductive heating is used at slow velocities only or when the heating temperatures are low.

What is claimed is:

1. A method of resistance annealing metal wires continuously in two electrical resistance heating steps to increase the size of metal crystals in the wire, and to decrease the strength and hardness while increasing the tensility of the wire comprising:

a. first subjecting a moving wire in a first step to a flow of electrical current therethrough for heating by electrical resistance to a temperature experimentally determined to create a controlled number of crystal nucleii; and next

b. cooling said wire after said first heating step; and

c. after said cooling subjecting the wire in a second heating step to a further flow of electrical current for the actual annealing at a higher temperature than that of the first step to crystallize the wire completely.

2. Method of claim **1**, in which the temperature of the wire is maintained from 400°to 500°C at the end of the first heating step and from 850°to 950°C at the end of the second heating step.

3. Method of claim **1**, in which a wire consisting of a metal selected from the group of copper and its alloys is subjected to the resistance annealing.

4. The method according to claim **1** wherein electrical current for said resistance heating is conducted to said wire by way of contact wheels over which the wire passes during treatment.

5. The method of claim **1** wherein the wire moves over a plurality of contact wheels, the heating of said first step being accomplished by passing current impulses through the wire between a first pair of said contact wheels, and the annealing of said second heating step being accomplished by passing current impulses through said wire between a second pair of contact wheels, the cooling between said heating steps occurring between said first and second pairs of contact wheels.

6. The method according to claim **5** wherein the wire is subjected to cooling by passage through a cooling bath.

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