



PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Method and Apparatus for Upsetting Steel Wires

of
Shimbashi

We, NIPPON CONCRETE KOGYO KABUSHIKI KAISHA, a Japanese corporation, of 8-3, 1-chome, ~~Chimbashi~~, Minato-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to methods of and apparatus for upsetting the end portions of steel wires, for example, steel tendons for tubular prestressed concrete, to form thereon enlarged heads for anchoring purpose.

It is the object of the present invention is to provide an upsetting method which makes it possible to produce headed steel wires with their head or upset portion having a strength at least comparable with that of their remaining portion and thus advantageously usable in the prestressing of concrete or other intended application in a reduced length of time with simple apparatus and easy operation.

The term "steel wires" as used in this specification is intended also to include what are called in practice steel bars.

Heretofore, for upsetting or enlarging end portions of steel wires, use has generally been made of a so-called header or upsetter in which the wire end is heated to an elevated temperature and worked under the pressure of the die in the machine to form an enlarged head somewhat like a rivet head. In the prior art, however, it has been impossible to avoid any reduction in strength of the wire end portion due to its heating, particularly, in cases where the wire is of high-carbon steel or heat-treated cold-drawn steel. In fact, it is not infrequent that such steel wire with its upset head is fractured at its neck when subjected to the tension test owing to the

reduction in strength of the worked wire portion.

In view of this, the inventor has conducted a large number of experiments with wires of different steel materials and found that what strength is obtained in the upset portion of the wire stock or whether the headed wire when tension tested will be fractured at its neck or at a point on its body portion depends definitely upon the correlation of the heating time and temperature used and that a satisfactory strength can be obtained at the wire neck portion even when it is worked at a considerably high temperature so long as the work is completed with a corresponding reduced heating time.

In the drawing, Fig. 1 illustrates one example of the result obtained with such experiments, and Fig. 2 is a schematic illustration of an upsetting apparatus, particularly showing its pneumatic system and electric circuitry.

In the experiments, the results of which are shown in Fig. 1, specimens were prepared by cold-drawing standard high-manganese high-carbon steel, including as main ingredients 0.80% C and 0.80 Mn, at a reduction ratio of approximately 50% to obtain steel wires of 7 mm. diameter, and upsetting such wires so as to form an enlarged head thereon which had twice as large a diameter as that of the wire body portion. Such specimens were subjected to tension tests by gripping their head and body portions and the location of fracture was recorded. In the rectangular coordinate system shown, the ordinate represents the heating time in seconds and the abscissa the temperature in °C. to which the wire stock is heated. The fractures occurring at a point on the wire body are each indicated in the graph by a small circle mark (O) and those occurring at the neck portion of the wire by a cross mark (X).

[Price 4s. 6d.]

It will readily be observed from the graphical illustration of Fig. 1 that:

(1) The heating time t has an upper limit t_0 for any heating temperature, inherent to the wire stock. If the wire is worked after being heated for any period of time extending beyond such limit t_0 , reduction in strength of the upset portion results.

(2) There is a definite relation between the heating temperature $T^{\circ}\text{C.}$, and such limit time t_0 seconds, which is expressed by the following formula:

$$(T - \alpha) \times t_0 = \beta \quad (\text{A})$$

where α and β are constants specific to the material and size of the stock. In the example of Fig. 1, $\alpha = 430$ and $\beta = 680$.

Thus the maximum heating time t_0 can be expressed as:

$$t_0 = \frac{\beta}{T - \alpha} \quad (\text{B})$$

and the heating time t which should be used to upset steel wire stock as:

$$t \leq \frac{\beta}{T - \alpha} \quad (\text{C})$$

A rational upsetting method is disclosed herein on the basis of such test results. With electric upsetters heretofore commonly used, supply and interruption of the working current have been effected upon the basis of the work size and in cases where the work is heated at a particularly high temperature, it is believed that the heating time generally exceeds the corresponding limit time t_0 and this, causing the material of the wire portion being upset to soften, results in reduction in strength of the worked material.

According to one aspect of the present invention there is provided a method of upsetting steel wires to form enlarged heads thereon, characterized in that the wire stock is worked at an elevated temperature satisfy-

ing the formula $t \leq \frac{\beta}{T - \alpha}$, where t represents the heating time in seconds, T represents the working temperature in $^{\circ}\text{C.}$, and α and β represent constants specific to the material and size of the wire stock.

Advantages of the present method include, besides the improvement in product quality, improvement in working efficiency, reduced resistance to deformation enabling not only higher extents of deformation but also simplification and reduction in size of wire grip and pressing means compared with those used in conventional cold or hot wire working pro-

cesses, and trim and satisfactory finish of the product.

According to a further aspect of the present invention, there is provided in an apparatus for upsetting steel wires to form enlarged heads thereon, including holder means for holding the wire stock, header means for heating and deforming the stock end to be headed, and pneumatic and electric means provided for automatic operation of said holder and header means; a combination of a variable transformer with means to control the magnitude of the heating current, pressure regulator valve means adapted to control the working speed of said header means, and timer means for controlling the time period during which the heating current is conducted to said header means, said timer means being adjustable to an appropriate time setting, the wire stock being worked to satisfy the formula

$t \leq \frac{\beta}{T - \alpha}$, where t represents the heating time in seconds, T represents the working temperature in $^{\circ}\text{C.}$, and α and β represent constants specific to the material and size of the wire stock.

The heating time t and temperature T should be selected relative to each other. With the apparatus disclosed herein, the temperature T is adjusted principally by voltage regulation by means of the variable transformer while the heating time t is controlled principally by operating the pressure regulator valve to vary the pressure acting upon the piston in the header assembly thereby to adjust its working speed. Once the temperature T and time t are properly selected at a point in the region beneath the curve of limit t_0 , any lot of wire stock can be successively worked to obtain desired uniform products with a predetermined neck strength unless any variation in the working conditions, for example, a sudden change in room temperature effective to vary the cooling rate or a possible variation in electric resistance of the wire stock causing change in the heating effect, occurs. It will be obvious that adjustment can also be made properly for such change in the working conditions.

It is to be understood that, where the wire stock to be worked varies in material, in diameter or in both, the specific constants α and β , in the formula (A), should be determined experimentally to obtain a corresponding limit curve, preliminarily to the adjustment of the machine to set the T and t values for the stock conforming to the working conditions desired.

The timer included in the apparatus for current supply and interruption is designed to function as follows:—

(1) Current supply in each cycle of upsetting operation is interrupted before the upsetting head reaches the end of its working

stroke as any heating during the final portion of the stroke hardly makes any contribution to the result obtained.

(2) The timer also serves the purpose of preventing overheating particularly when the voltage has been regulated to a particularly high value.

(3) Use of the timer, made in a variable type, makes it easier to deal with different changes in working conditions.

Reference will next be made to Fig. 2, which illustrates one preferred embodiment of the apparatus, particularly showing its pneumatic system and electric circuitry.

In Fig. 2, the chuck 1 adapted to grip and hold a wire stock W is comprised of a fixed member 3 and a movable member 2 both of steel and each having a toothed engaging surface 4 or 5 to grip and hold wire stock W firmly in place. The movable member 2 is actuable by a piston 6 with its rod 7. Copper electrodes 8 and 9 are fixed to movable and fixed chuck members 2 and 3 respectively, in an insulated relation thereto, and so arranged as to make contact with the wire stock W when it is gripped by the chuck 1. The fixed electrode 9 is grounded. Piston member 6 is operably received in a pneumatic cylinder 12 which communicates with a conduit 16 carrying a pressure switch S₁ and with another conduit 16a which is joined with the conduit 16 by means of a solenoid valve 14.

Reference numeral 20 indicates a working head which serves to upset the adjacent end portion of wire stock W and is mounted on the end of the rod 22 of a piston 21 in an insulated relation thereto. As shown, the piston 21 is operably received in a separate pneumatic cylinder 23 and communicating with conduits 25 and 25a joined together by solenoid valve 24. A finger 26 is carried on the piston rod 22 to serve the purpose of actuating a limit switch S₂. The two solenoid valves 14 and 24 are also connected with conduits 28 and 29, respectively, which branch off a main air line 27 communicating with an appropriate air pressure source not shown. Pressure regulator valves 30 and 31 as well as pressure gauges 33 are attached to the branch conduits 28 and 29, respectively.

The pressure switch S₁, limit switch S₂, and solenoids L₁ and L₂ of respective electromagnetic valves 14 and 24 are arranged in the circuit shown in Fig. 2, which is connected to an appropriate electric source and includes a foot-operated switch S, an auxiliary relay R, a variable timer T, a magnet switch M and a variable transformer Tr.

The illustrated apparatus operates as follows:

(1) When main or foot-operated switch S is depressed, the solenoid L₁ of electromagnetic valve 14 is energized to allow air pres-

sure from branch conduit 28 to proceed through conduit 16 into the space in the cylinder 12 lying on one side of the piston 6 while communicating the cylinder space on the other side of the piston 6 with a discharge outlet through conduit 16a. Consequently, the piston 6 is forced downwards together with the movable chuck member 2 so that the wire stock W to be worked is held in the chuck 1.

(2) When the holding pressure of chuck 1 is built up to a predetermined level, the air pressure set in the cylinder 12 and conduit 16 acts to close pressure valve S₁ thereby energizing timer T.

(3) The closing of pressure valve S₁ is also effective to close solenoid switch M thereby to apply voltage to header electrode 20. The solenoid L₂ of electromagnetic valve 24 is also energized upon the closing of pressure valve S₁ so that the valve 24 is operated so as to introduce air pressure from the branch conduit 29 into the right-hand side of the header cylinder 23 through conduit 25 while communicating the left-hand side of the cylinder 23 with a discharge outlet through conduit 25a. As the result, the upsetting head 20 carried on the end of the piston rod 22 is advanced leftwards to engage the adjacent end of wire stock W thereby to start current supply to the work and its deformation under compression.

(4) Subsequently, as soon as the predetermined time previously set on the timer lapses, solenoid switch M is opened to interrupt the current supply to the work whereas the header cylinder 23 remains activated to continue leftward movement of header 20 and therefore deformation of work W.

(5) At the instant when the end of the wire stock W has been collapsed to form a rivet-head-like enlargement of a predetermined size, limit switch S₂ is operated by the finger 26 carried by piston rod 22 and solenoid L₂ is restored under the self-holding action of relay R whereby the piston 21 in the header cylinder 23 is moved back to its normal position. Then, foot-operated switch S is released to restore the solenoid L₁ whereby the piston 6 in chuck cylinder 12 is moved back to release the chuck 1 and the cycle of operation is completed.

For such cyclic operation, the working temperature is adjusted by notching the control arm 34 of transformer Tr to current. It is to be noted that, with the lever position properly selected, a heating time t which satisfies the relation $t < t_c$, where t_c is the limit time satisfying the formula (A) for the working temperature, can be obtained by manual or automatic setting of the timer T.

WHAT WE CLAIM IS:—

1. A method of upsetting steel wires to form enlarged heads thereon, characterized



stroke as any heating during the final portion of the stroke hardly makes any contribution to the result obtained.

(2) The timer also serves the purpose of preventing overheating particularly when the voltage has been regulated to a particularly high value.

(3) Use of the timer, made in a variable type, makes it easier to deal with different changes in working conditions.

Reference will next be made to Fig. 2, which illustrates one preferred embodiment of the apparatus, particularly showing its pneumatic system and electric circuitry.

In Fig. 2, the chuck 1 adapted to grip and hold a wire stock W is comprised of a fixed member 3 and a movable member 2 both of steel and each having a toothed engaging surface 4 or 5 to grip and hold wire stock W firmly in place. The movable member 2 is actuable by a piston 6 with its rod 7. Copper electrodes 8 and 9 are fixed to movable and fixed chuck members 2 and 3 respectively, in an insulated relation thereto, and so arranged as to make contact with the wire stock W when it is gripped by the chuck 1. The fixed electrode 9 is grounded. Piston member 6 is operably received in a pneumatic cylinder 12 which communicates with a conduit 16 carrying a pressure switch S_1 and with another conduit 16a which is joined with the conduit 16 by means of a solenoid valve 14.

Reference numeral 20 indicates a working head which serves to upset the adjacent end portion of wire stock W and is mounted on the end of the rod 22 of a piston 21 in an insulated relation thereto. As shown, the piston 21 is operably received in a separate pneumatic cylinder 23 and communicating with conduits 25 and 25a joined together by solenoid valve 24. A finger 26 is carried on the piston rod 22 to serve the purpose of actuating a limit switch S_2 . The two solenoid valves 14 and 24 are also connected with conduits 28 and 29, respectively, which branch off a main air line 27 communicating with an appropriate air pressure source not shown. Pressure regulator valves 30 and 31 as well as pressure gauges 33 are attached to the branch conduits 28 and 29, respectively.

The pressure switch S_1 , limit switch S_2 , and solenoids L_1 and L_2 of respective electromagnetic valves 14 and 24 are arranged in the circuit shown in Fig. 2, which is connected to an appropriate electric source and includes a foot-operated switch S, an auxiliary relay R, a variable timer T, a magnet switch M and a variable transformer Tr.

The illustrated apparatus operates as follows:

(1) When main or foot-operated switch S is depressed, the solenoid L_1 of electromagnetic valve 14 is energized to allow air pres-

sure from branch conduit 28 to proceed through conduit 16 into the space in the cylinder 12 lying on one side of the piston 6 while communicating the cylinder space on the other side of the piston 6 with a discharge outlet through conduit 16a. Consequently, the piston 6 is forced downwards together with the movable chuck member 2 so that the wire stock W to be worked is held in the chuck 1.

(2) When the holding pressure of chuck 1 is built up to a predetermined level, the air pressure set in the cylinder 12, and conduit 16 acts to close pressure valve S_1 thereby energizing timer T.

(3) The closing of pressure valve S_1 is also effective to close solenoid switch M thereby to apply voltage to header electrode 20. The solenoid L_2 of electromagnetic valve 24 is also energized upon the closing of pressure valve S_1 so that the valve 24 is operated so as to introduce air pressure from the branch conduit 29 into the right-hand side of the header cylinder 23 through conduit 25 while communicating the left-hand side of the cylinder 23 with a discharge outlet through conduit 25a. As the result, the upsetting head 20 carried on the end of the piston rod 22 is advanced leftwards to engage the adjacent end of wire stock W thereby to start current supply to the work and its deformation under compression.

(4) Subsequently, as soon as the predetermined time previously set on the timer lapses, solenoid switch M is opened to interrupt the current supply to the work whereas the header cylinder 23 remains activated to continue leftward movement of header 20 and therefore deformation of work W.

(5) At the instant when the end of the wire stock W has been collapsed to form a rivet-head-like enlargement of a predetermined size, limit switch S_2 is operated by the finger 26 carried by piston rod 22 and solenoid L_2 is restored under the self-holding action of relay R whereby the piston 21 in the header cylinder 23 is moved back to its normal position. Then, foot-operated switch S is released to restore the solenoid L_1 whereby the piston 6 in chuck cylinder 12 is moved back to release the chuck 1 and the cycle of operation is completed.

For such cyclic operation, the working temperature is adjusted by notching the control arm 34 of transformer Tr to current. It is to be noted that, with the lever position properly selected, a heating time t which satisfies the relation $t < t_0$, where t_0 is the limit time satisfying the formula (A) for the working temperature, can be obtained by manual or automatic setting of the timer T.

WHAT WE CLAIM IS:—

1. A method of upsetting steel wires to form enlarged heads thereon, characterized

in that the wire stock is worked at an elevated temperature satisfying the formula $t \leq \frac{\beta}{T-a}$, where t represents the heating time

in seconds, T represents the working temperature in °C., and a and β represent constants specific to the material and size of the wire stock.

2. In an apparatus for upsetting steel wires to form enlarged heads thereon, including holder means for holding the wire stock, header means for heating and deforming the stock end to be headed, and pneumatic and electric means provided for automatic operation of said holder and header means, a combination of a variable transformer with means to control the magnitude of the heating current, pressure regulator valve means adapted to control the working speed of said header means, and timer means for controlling the time period during which the heating current is conducted to said header means, said timer means being adjustable to an appropriate

time setting, the wire stock being worked to

satisfy the formula $t \leq \frac{\beta}{T-a}$, where t represents the heating time in seconds, T represents the working temperature in °C., and a and β represent constants specific to the material and size of the wire stock.

3. A method of upsetting steel wires to form enlarged heads thereon, the method being substantially as hereinbefore described with reference to the accompanying drawing.

4. An apparatus for upsetting steel wires to form enlarged heads thereon as claimed in claim 2, the apparatus being substantially as hereinbefore described with reference to the accompanying drawing.

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