Jan. 19, 1954 L. DREYFUS 2,666,830

METHOD AND FURNACE FOR HEATING BARS TO BE FORGED BY MEANS OF EDDY CURRENTS

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Fig.1

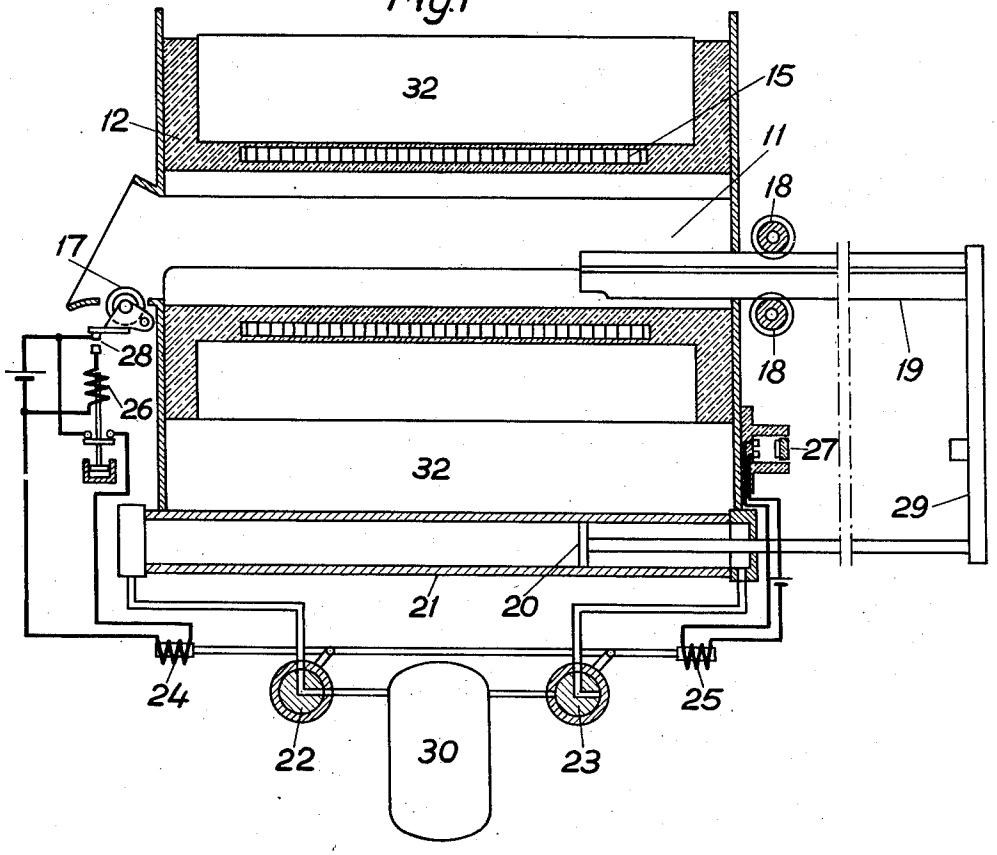
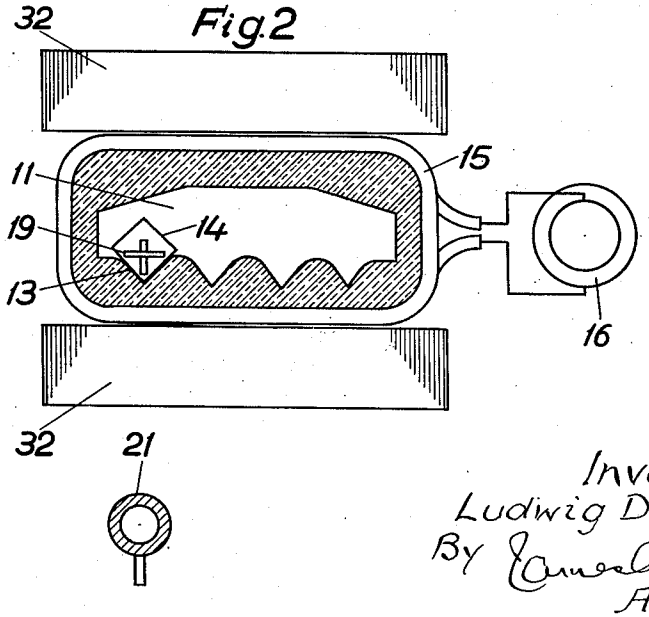


Fig.2



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Fig.3

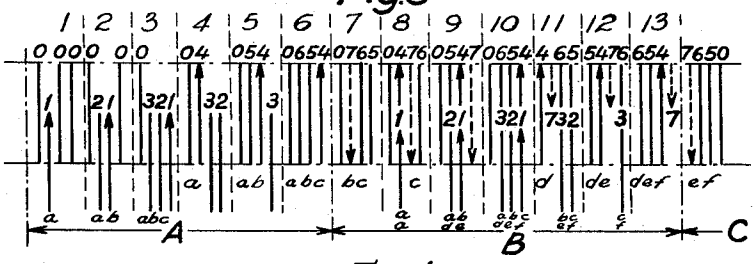


Fig.4

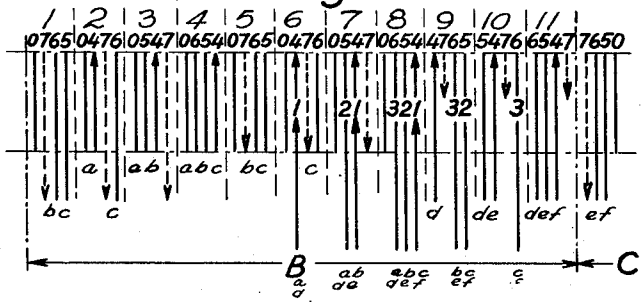


Fig.5

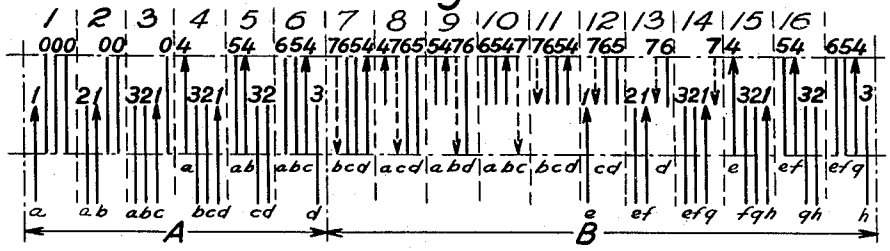
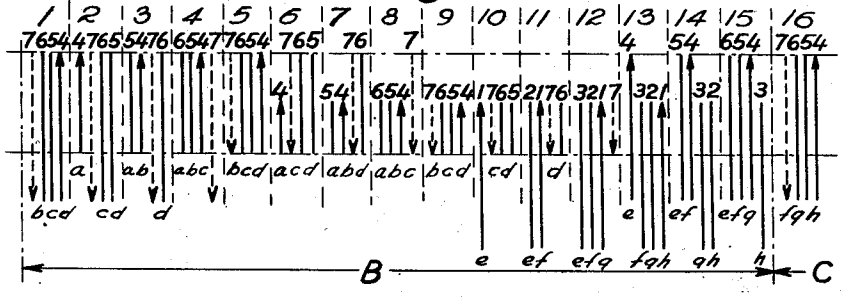


Fig.6



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2,666,830

METHOD AND FURNACE FOR HEATING BARS TO BE FORGED BY MEANS OF EDDY CURRENTS

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Claims priority, application Sweden December 21, 1949

10 Claims. (Cl. 219—3)

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A frequently used procedure in forging, especially in forging a large number of substantially similar pieces, is one in which the different pieces are shaped from the end of a bar-shaped blank and then severed from the bar. After this is done, the bar end is heated again and the next part is forged, and so forth. In such a procedure, the extreme portion of the bar remaining after severing is necessarily close to the forging temperature. If the bar is then heated again—which to avoid loss of time and heat should preferably be done immediately—this causes no difficulty if the heating is effected in a fired furnace, since the maximum temperature is then determined by the furnace flame, the temperature of which can always be adjusted so as not to overheat the work piece. If, on the other hand, the heating is done in an electric eddy current furnace, which otherwise is preferable for various reasons, there will be no upper limit of the temperature, but the heat supply per unit of time and per unit of surface of the bar will be substantially independent of its preceding temperature, and therefore there is danger that the bar end may be overheated and even melted.

According to the present invention, a method is applied in heating bar blanks in an eddy current furnace, preferably a high frequency furnace, which eliminates the aforesaid risk of overheating and at the same time enables the furnace to be employed for bar blanks of varying lengths. The invention is principally characterized by the fact, that the heating is performed in two or more steps in such manner that, when the end portion of the bar is heated to full forging temperature, the portion lying next to it is heated to an intermediate temperature, sufficiently high to reach full forging temperature after another heating step. The difference of temperature between the portion being forged and the next portion will then be moderate, and also, when the forged piece has been cut off, the temperature of the tip of the remaining part of the bar will be so little in excess of that of the portion next to be forged, that the tip is not likely to be overheated during the next heating step. As a rule, it is sufficient to heat in two steps, especially in the case of steel having magnetic properties, the heating of which by means of eddy currents takes place at a considerably higher speed up to the magnetic transformation point than above this point, so that the bar, for instance with heating steps of equal length, can be heated to about 900° C. during the first step and to about 1150° C. during the second step. The temperature difference will therefore

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only be about 250° C., which may be tolerated without risk of overheating the tip.

As a rule the heating—the intensity of which is limited by the necessity of avoiding a superheating of the surface of the bar—takes several times the time necessary for the forging. The average proportion between heating time and forging time will vary between 4 and 6 to 1. In order to give the best possible economy of time and heat, the furnace is therefore provided, according to the present invention, with a number of heating positions, which is one more than the ratio between the aforesaid time proportion and the number of heating steps. Thus if the proportion between heating time and forging time is 6 to 1, as has been assumed, and the number of heating steps is 2, the number of heating positions should preferably be

$$\frac{6}{2}+1=4$$

The extra heating position serves as a kind of reserve, the purpose of which is explained below.

In the accompanying drawing, Fig. 1 shows a vertical longitudinal section and Fig. 2 a vertical cross section of a furnace according to the present invention for practising the method of the said invention. Figs. 3–6 show diagrammatically four examples of applying the invention to different proportions between bar length and forging length.

Referring to Figs. 1 and 2, the furnace may have the shape of a muffle 11 with walls of refractory material 12 and having at its bottom four parallel grooves 13, for instance of triangular cross-section, for receiving bars of square cross-section lying edge-wise. One such bar 14 is shown in the groove to the left. The muffle is surrounded by a coil-shaped winding 15 through which a high frequency current is passed from a generator 16. Laminated iron shells 32 embrace said winding. The winding may be provided, in the usual manner, with one or more condensers for compensating the reactive power consumption thereof, and could further be divided into different portions, substantially as described in my pending patent application Serial No. 154,142, to enable the furnace to be economically employed for heating bars of different lengths. Rollers 17 in front of the furnace serve to support and guide the bars when they are pushed into the furnace, which for instance may be made by hand, and other rollers 18 at the rear end of the furnace serve to guide and support rods 19 (partly cut away in the drawing) which act to push the bars out from the furnace, for

instance when a certain time has elapsed from the instant of their introduction. A timing device is diagrammatically shown for this purpose and will be described in detail hereinafter. The instant of expulsion of the bars may also be determined by a pyrometric apparatus.

The expulsion rods 19, only one of which is shown, are in the example illustrated maneuvered by a piston 20 in a cylinder 21. Compressed air can be admitted alternatively to the ends of said cylinder and expelled therefrom by means of three-way cocks 22, 23. These cocks are controlled by means of two electromagnets 24, 25. Current is admitted to the electromagnets 24 through a retarded relay 26 which is excited through contacts 28 operated by the roller 17. The electromagnet 25 is controlled directly by a contact device 27 which is operated by a cross-head 29 supporting the outer end of the expulsion rod 19.

When a bar to be heated is introduced into the furnace, the corresponding roller 17 is depressed and closes the contacts 28 so that the relay 26 is energized. On account of the retarding means of said relay, it does not close its contacts until a certain time has elapsed, and, when this is done, the cocks 22 are placed in such position as to admit compressed air from the receptacle 30 to the right end of the cylinder 21 and to open the communication between the left end of said cylinder and the open air. The piston 20 is then moved to the left, and the rod 19 moves in the same direction and expels the heated bar from the furnace. When the cross-head 29 strikes the contact device 27, current is admitted to the electromagnet 25, whereby the cocks 22, 23 are restored to their original position in which compressed air is admitted to the left end of the cylinder 21 so as to restore the piston and the expulsion rod to their extreme right position.

In Figs. 3–6, the bars to be forged are diagrammatically represented by simple lines, in some cases dotted as further specified below. In each figure, these lines are arranged in groups separated by vertical dash lines, and these separate groups represent different time intervals in the heating process, while the lines contained in each group represent different heating grooves in the furnace. The two ends of the said heating grooves, which are the limits of the heating zone, are in each figure represented by the horizontal dot and dash lines. At the upper end, the heating zone may of course extend further although only the portion thereof limited by the dot and dash line is utilized for the purpose of the present invention. The vertical lines designated by 0 represent empty grooves, while the lines designated by other numerals represent bars to be heated—showing their length as well as their positions—during time intervals corresponding in length to the forging time, each numeral representing the stage of heating of the corresponding bar. The arrows, where present, represent the direction of motion of each bar at the beginning of the time interval represented, dotted lines representing a recent expulsion of the corresponding bar.

Fig. 3 refers to the forging of pieces which embrace half of the bar length. The group of lines at the left end of the figure represents the first time interval after the starting of the furnace. During this interval, the grooves should be empty, since it is presumed that only one work piece can be worked at a time, and since no piece must be overheated. Three grooves thus have the numeral 0 and the fourth one—the second from the left—contains a bar *a* which has just been inserted half the length of the groove and is designated by 1, since the first stage of heating is involved.

In the second group, counted from the left end, two grooves are still empty, in one—designated by 2—the aforesaid bar *a* still rests and is subjected to its second heating stage, and in another one a fresh bar *b* has been introduced, so that its position is designated by 1.

In the third group of lines, there is only one empty groove and three half-filled ones, designated by 1, 2, 3 in correspondence with the heating intervals to which the bars *c*, *b* and *a* respectively are then subjected. At the end of this interval, the bar *a* has passed half of its heating time and has thus—according to the example hereinbefore given—reached a temperature of about 900° C., whereupon it is preferably expelled from the groove.

In the fourth group, one groove is still empty, while the bar *a* has been expelled and has now been introduced again at 4 to the full length of the groove, so that its end portion passes through its fourth heating interval and the next portion of the bar its first one.

In the fifth group, another recently expelled bar *b*, here designated by 4, has been introduced to the full length of the groove and its end portion has begun its fourth heating interval, while the end portion of bar *a* passes through interval 5 and of bar *c* through interval 3. One groove is still empty.

In the sixth group, which is separated from the following one by a vertical dot and dash line, marking the end of the first or "charging" period A of the furnace, one bar *a*, designated by 6, passes through its last heating interval, after which it is ready for forging, while two other ones *b* and *c* pass through the intervals 5 and 4, bar *c* having been expelled and introduced to the full length of the groove.

After the end of the time interval represented by the sixth group, the ready-heated bar *a* is expelled, preferably by an automatic device such as that shown in Figs. 1 and 2, and the corresponding bar position is therefore marked by a dotted line in the seventh group and marked by the numeral 7 and by an outwardly directed arrow. During this interval, the end of the heated bar *a* is forged and then cut off from the rest of the bar. Theoretically, it could be possible to introduce a fresh bar into the groove which has just been emptied, but since this groove is blocked—at the beginning of the interval—by the bar *a*, it would be necessary first to remove this bar, then to introduce a fresh bar and then to pick up the bar *a* again and to transport it to a forging machine. As it is not practical to retard the work of the blacksmith by these extra maneuvers, the said method would necessitate an additional helper, and therefore it is hardly economical. It is therefore advisable to leave the just emptied channel 7 empty during one time interval.

When the portion of bar *a* which was first heated has been forged to the desired shape and cut off, the remaining portion of bar *a* is again introduced into an empty heating groove, and behind it one half of a fresh bar *d* is introduced, as shown in the eighth group from the left in Fig. 3. The first-named bar portion 2, which has previously passed through three heating intervals, has here

the numeral 4, while the freshly introduced bar *d* has the numeral 1. The bar lying in the position marked by 7 is fully-heated and is expelled at the beginning of the interval and then forged. The procedure continues in an analogous manner during the next two intervals, the ninth and tenth ones, introducing bars *e* and *f* respectively behind the halves of bars *b* and *c*.

At the beginning of the eleventh interval, the portions of bar *a* designated by 6 in the tenth interval which is now fully heated is expelled, but, in order to accomplish this, the bar *d* lying in its way must also be expelled, whereupon it is introduced during the eleventh interval in the groove which has heretofore been empty. In this groove, the end portion of this bar *d* now passes through its fourth heating interval and therefore in this group is marked by the numeral 4. The conditions will be analogous during the two following intervals, thus the bar *e* marked by 3 in the eleventh interval is expelled together with the half of bar *b* which is fully-heated. The bar *e* is transferred to the second groove which was empty before, and the ready-heated half bar *b* is forged. In the thirteenth interval, bar *f* and half of bar *c* are removed and bar *f* is reintroduced into the third groove while the end part of bar *c* is forged.

During the fourteenth interval, upon the removal of bar *d*, the conditions of the seventh one are exactly repeated, only with difference that a different groove is empty, and thereby the next cycle C of seven intervals is begun, which will be a repetition of the preceding cycle B. Such cycles then follow each other as long as the forging goes on.

Fig. 4 illustrates a procedure in forging bars which embrace three work pieces each. The horizontal dot and dash lines still designate the limits of the heating zone which, however, may extend further upwards. The substantial difference with respect to Fig. 3 is that Fig. 4 only shows the continuous conditions, i. e. that the first group (from the left) corresponds to the seventh one in Fig. 3, apart from the greater length of the bars. The intervals 5 to 12 are entirely identical to the intervals 7 to 14 in Fig. 3. The introduction of a fresh bar behind a half preheated one thus begins in Fig. 4 with the sixth interval therein shown, and the transfer of a bar to the previously empty groove begins first with the ninth interval. With the twelfth interval, a new cycle begins which is identical to the preceding cycle of eleven intervals. During the fourth and eighth intervals, no forging takes place, whence the utilisation of time is somewhat inferior to that of Fig. 3, where during the cycles B, C etc. only one interval out of seven (the tenth one) is not utilized for forging. For a bar embracing n work piece lengths, the cycles B, C etc. will embrace $4n-1$ heating intervals, $n-1$ of which are not utilized for forging.

Figs. 5 and 6 illustrate working procedures which offer certain advantages as compared with those shown in Figs. 3 and 4. First, in Figs. 5 and 6, portions of two bars never lie in the same groove, which positioning may cause one bar end to ride over the other during the expulsion which may thus be obstructed. Secondly, during each cycle of continuous operation, all intervals without forging follow each other immediately, so that they may be better utilized for rest pauses, for cleaning the forging tools, etc. In Fig. 6, furthermore, the end of the working pieces which the blacksmith holds by his tongs during the

forging of the last piece of a bar, will have a somewhat lower temperature than the rest of the work piece, which will not be the case according to Figs. 3–5.

Fig. 5 refers to the forging of bars having two working lengths and Fig. 6 to the forging of bars having three such lengths. Fig. 5 corresponds in its general arrangement to Fig. 3, i. e. it also embraces the six starting intervals during which the furnace is only being charged, before the continuous operation has begun. The difference with respect to Fig. 3 is first, that a bar *d* is introduced into the previously empty groove at the beginning of the fourth interval, so that the cut-off half of bar *a* may occupy a groove alone when its heating is to be completed. During the fifteenth, sixteenth and seventeenth intervals which are consecutive, no forging takes place, but forging takes place during all the other ones, after the continuous conditions have been reached (cycle B).

Fig. 6 also involves an earlier utilisation of the initially empty groove, in analogy with Fig. 5, although Fig. 6 only shows the continuous state, i. e. begins with the interval in which the forging begins. In the first interval of this figure, a bar *a* of the full length, designated by 7, is expelled, and its extreme third part is forged and cut off; the remaining two thirds are introduced into the empty groove at the beginning of the next interval. During the three intervals following the first one, three further bars, *b*, *c* and *d* are treated in an analogous manner. During the fifth interval, the first bar *a* shortened to ⅔, is expelled and forged (whence this interval corresponds to the seventh one in Fig. 5), but at the beginning of the sixth interval, the remaining third portion of this bar *a* is introduced into the front half of the empty groove, so that its end which is to be held by the tongs will lie close to the end of the heating zone or somewhat outside the latter and therefore is kept cooler than the rest of the bar. (Only in this respect does Fig. 6 differ from Fig. 5 in principle.) The manner of operation following that described is seen from the figure. After fifteen intervals, a complete cycle B has been traversed and the whole cycle is repeated. The forging pauses here occur during the last three intervals of the cycle, i. e. the thirteenth, fourteenth and fifteenth ones, when the grooves are again filled after having been only half-filled before, no bar being then ready for forging. When a bar, embracing n work pieces, is to be heated in a furnace containing k grooves, the period has, in the continuous state, $kn+k-1$ intervals, while during $k-1$ intervals thereof no forging takes place.

The application of the method on heating zones for more than two work piece lengths, corresponding to more than two heating steps, can be simply derived from the examples described.

I claim as my invention:

1. A method of heating bars in eddy current furnaces for being forged, consisting in first heating a portion only of a bar in said furnace by inducing eddy currents in said portion to a temperature substantially below forging temperature, then moving said bar to another position in said furnace, further heating said portion of the bar by inducing eddy currents in said portion while it is retained in such second position to a substantially higher temperature and simultaneously with such further heating heating a second portion of the bar to a substantial tem-

perature substantially below forging temperature.

2. In a method as claimed in claim 1, said first portion forming one-half of the bar and being heated in the first position to a temperature above the magnetic transformation point of the bar but substantially below forging temperature and in such second position to forging temperature.

3. A method of heating bars in eddy current furnaces and forging said bars in part, comprising the step of heating a portion only of each bar to forging temperature by inducing eddy currents therein, and simultaneously with such heating heating an adjacent portion of said bar to a substantial temperature considerably below forging temperature by inducing eddy currents in said adjacent portion, forging a portion of another bar simultaneously with the heating of said first-named bar, and discontinuing such forging during several successive steps of heating bars.

4. An eddy current furnace having induction heating means and having a plurality of heating grooves for heating bars intended to be forged one part at a time, the length of each heating groove being an integral multiple of the length of each part intended to be forged, said grooves being open at one end and closed at the other.

5. An eddy current furnace for heating a plurality of bars intended to be forged one part at a time, said furnace having induction heating means and having a number of heating grooves for said bars which number is one unit more than the ratio between half the time necessary for heating to forging temperature and the time necessary for forging.

6. An eddy current furnace as claimed in claim 4, said furnace having induction heating means and having automatic expulsion means for expelling each bar a certain time after its introduction corresponding to the time necessary for heating the part to be forged in a direction opposite to that in which it was introduced.

7. A method of heating bars in eddy current furnaces for forging, which comprises first inserting a portion only of a bar into one position in the heating zone of the furnace while leaving a second portion of the bar outside said heating zone, heating the first portion of the bar in such position by inducing eddy currents in such portion to a temperature substantially below forging temperature, and then moving said bar to a second position in which said first portion occupies a different position within the heating zone of the furnace and both portions are within the heating zone, further heating said first portion to a substantially higher temperature while retaining the bar in such second position and simultaneously heating the second portion

to a temperature substantially below forging temperature by inducing eddy currents in both such portions.

8. A method of heating and forging bars, which comprises first inserting a portion only of a bar into one position in the heating zone of an eddy current furnace while leaving a second portion of the bar outside said heating zone, heating the first portion of the bar in such position by inducing eddy currents in such portion to a temperature substantially below forging temperature, and then moving said bar to a second position in which said first portion occupies a different position within the heating zone of the furnace and both portions are within the heating zone, further heating said first portion to a substantially higher temperature while retaining the bar in such second position and simultaneously heating the second portion to a temperature substantially below forging temperature by inducing eddy currents in both such portions, removing the bar from the furnace, forging the first portion of the bar and separating it from the second portion of the bar, returning the second portion to the furnace and heating it further therein, and forging such second portion.

9. A method of heating bars for forging which comprises introducing said bars into an eddy current furnace having induction heating means and having a plurality of bar receiving grooves therein, and heating a part of a bar at each heating step by inducing eddy currents therein, the length of the grooves being an integral multiple of the length of the part heated.

10. A method of heating and forging bars, which comprises introducing said bars into an eddy current furnace having induction heating means and having a plurality of bar receiving grooves therein, heating a part of a bar at each heating step by inducing eddy currents therein, and forging such heated part, the number of grooves being one more than the number representing the value of the ratio between half the time necessary for heating to forging temperature and the time necessary for forging.

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