PROCESS AND APPARATUS FOR PRESS-FORMING AND QUENCHING A STEEL STOCK

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ABSTRACT

The invention relates to a process and apparatus for press-forming and quenching a steel stock such as diaphragm spring for automotive clutch use. In the invention, the stock is preparatory heated to its austenitizing temperature such as about 800°C, or so, placed on one of two cooperating die elements, and then squeezed therebetween under pressure, said die elements having working surfaces having corresponding dimensions and configurations so as to be brought into a pressurized and heat-conducting contact with the to-be-quenched zone of said stock, thereby said stock being press-formed to its desired shape and wholly or locally quenched to a desired hardness such as HRC 60° by conducting substantial amount of heat from the stock to the die elements.

8 Claims, 10 Drawing Figures
FIG. 1

FIG. 2

FIG. 6

ATTAINABLE FINAL TEMPERATURE, °C

M$_S$ - POINT OF RESPECTIVE STEEL

THERMAL CAPACITY RATIO:

THERMAL CAP. OF COOLING TOOL

THERMAL CAP. OF STOCK TO QUENCHD
FIG. 5

THERMAL PENETRATION RATE, \( \text{in/\text{m} \cdot \text{s} \cdot \text{K}} \)

SANDSTONE

S45C  SCR4  SCM4  SNCM8

IDIAL CRITICAL DIAMETER, \( D_1 \) inch

FIG. 8

HARDNESS AFTER QUENCHING, HRC

THICKNESS OF SAMPLE UPON TREATED

PRESSURE APPLIED ON SAMPLE, KGS. PER SQ. CENTIMETER
PROCESS AND APPARATUS FOR PRESS-FORMING AND QUENCHING A STEEL STOCK

This invention relates generally to certain improvements in and relating to the press-forming and quenching techniques. It relates more specifically to a process for press-forming and quenching steel sheet products and an apparatus adapted for carrying out said process.

According to the prior technique, steel sheets intermediate or final products, as the case may be, are manufactured in successive and separate steps of press-forming and quenching. As is commonly known, the quenched products may frequently represent considerable distortion from the desired shape and thus an additional and tedious step such as hammering, press-tempering or the like must be employed for removing such distortion developed in the quenching step. Inviation of the distortion after quenching will naturally reduce the degree of precision in shape and dimension of the products.

It is therefore the main object of the invention to provide a process, as well as an apparatus for press-forming and quenching steel sheet products, capable of obviating the conventional drawback of necessitating the aforementioned kind of additional correction service successive to the quench step.

A further object is to provide a process as well as an apparatus of the above kind, capable of improving the degree of precision in shape and dimension of the quenched products in spite of the omission of the conventionally adopted correction service.

For attaining the aforesaid objects, it is now proposed to place a steel stock between a pair of cooperating die elements upon heating said stock to its austenitizing temperature and to provide pressure upon said stock and at the same time rapidly to conduct heat from said stock to said die elements by keeping the latter at a cooling temperature during the whole processing, thereby a quench effect upon said stock under forming pressure.

An apparatus for carrying out the above process, comprises an upper die element having a working surface made in registration with the corresponding finished surface of the stock, a lower die element having a working surface made in registration with the corresponding finished surface of the stock; an actuating power means for moving said die elements towards each other and separating from each other, for applying a mechanical pressure upon said stock when the latter is squeezed between said die elements when said actuating means is brought into actuation in the direction towards relative engagement of the die elements; and cooling means for said die elements, thereby said stock being subjected to cooling for quenching as well as forming to its desired shape when squeezed between the cooled die members under pressure.

An actuating means is preferably shaped into a hydraulic piston-and-cylinder unit operable by the will of an operator, either of said piston or cylinder being mechanically connected with one of said die elements for driving them as desired for the press-forming and quenching job. The cooling means is preferably formed into a cooling chamber provided in each of the die elements and arranged to receiving a circulating stream of coolant.

These and further objects, features and advantages of the invention will become more apparent when read the following detailed description of the invention by reference to the accompanying drawings.

In the drawings:

FIG. 1 is a top plan view of a diaphragm spring destined for use in an automotive clutch assembly, and indeed, as a representative example of the products manufactured according to the improved technique proposed by the invention.

FIG. 2 is a side view of the diaphragm spring shown in FIG. 1.

FIG. 3 is an elevational view of an apparatus adapted for use in the practice of the process according to the invention.

FIG. 4 is an enlarged sectional elevation of several main working elements of the apparatus shown in FIG. 3.

FIG. 5 is an explanatory chart in which the thermal penetration rate, Kcal/m²·Ch², of the tool has been plotted against the ideal critical diameter in inches, of the work, as a representative example in the practice of the process according to this invention.

FIG. 6 is a further explanatory chart showing the relationship between the theoretical final temperature, °C., attainable in the work upon quenching, on the one hand, and the thermal capacity ratio which means more specifically the relative ratio between the thermal capacity of the tool to provide quenching and that of the work to be quenched.

FIG. 7 is a still further explanatory chart illustrative of the relationship between the hardeness of quenched work samples as processed by the process according to the invention and the thicknesses of the samples.

FIG. 8 is a still further explanatory chart illustrative of the influence upon the hardness as well as the thickness of the product processed in accordance with the invention, by the processing pressure.

FIG. 9 is a similar view to FIG. 4, wherein a selectively localized quenching is being carried into effect as a modified mode of the process according to this invention.

FIG. 10 is a still further explanatory chart illustrative of a distributed hardness developed on the surface of a work piece processed in accordance with the modified mode of the invention shown in FIG. 9.

Referring now to FIGS. 1 and 2 of the drawings, the kind and nature of a representative work piece, or more specifically a diaphragm spring for automotive clutch use and the conventional technique of the press-forming and the quenching thereof will be briefly described for the illustration of technical background of the present invention.

The diaphragm spring 100 has a generally dish-shaped configuration and comprises a peripheral ring-shaped main spring body part 101 and a number of radially arranged lever-like portions 102 which extend concentrically from said main body part 101 towards the center of the diaphragm when seen in its top plan view shown in FIG. 1. Each of said lever-like portions 102 has a gradually reducing width and there is an open circular area defined by a circle connecting the innermost or top free ends 103 of all the lever portions 102 when seen in FIG. 1.

It will be clearly seen from the foregoing description and by judgement from the drawing that the diaphragm spring 100 represents a rotational symmetry about its central axis and has generally a truncated cone shape. The diaphragm spring is made generally of a kind of high carbon steel and the lever ends 103 must be hardened so as to provide a possible minimum sliding wear in sliding contact with a conventional automotive clutch release bearing not shown, while the remaining parts of the diaphragm spring must have generally a spring characteristic as such.

In order to satisfy the aforementioned specific requirements, the diaphragm spring is manufactured through the following several successive fabricating steps:

a. a generally circular stock is pressed out from a large size steel sheet material, so as to represent a number of lever-like portions 102 and a ring-shaped main body part 101 integral therewith.
b. the thus pressed-out plane stock is shaped generally into a truncated cone on a forming press.
c. the thus shaped truncated cone stock is heated at about 850 °C. for about 20 minutes and then quenched therefrom into an oil bath for hardening of the product as a whole.
d. the quenched stock is then heated at about 320 °C. for about 90 minutes and then air-cooled to normal temperature for performing a provisional tempering.
e. the thus provisionally tempered stock is heated at about 450 °C. for about 80 minutes and then air-cooled to normal temperature for carrying out a press-tempering so as to remove the overall distortion.
f. the thus press-tempered stock is subjected to a high frequency induction hardening substantially at the end extremities of the lever portions.
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g. the lever portions are subjected to a tempering step. It may be therefore understood that according to the prior technique for the manufacture of the diaphragm spring of the above kind, the whole process requires a longer treating period as well as a highly skilled workmanship, on account of separately applied quenching and repeatedly applied tempering steps, as specifically appearing in the foregoing items c–e and especially for the purpose of removing unavoidably developed thermal deformation.

It is proposed by the present invention to carry out several processing steps as at b–e, beginning from the press-forming and ending with the deformation removal tempering, exclusively in one step and in a shortest possible time period in such a way that a steel stock pressed out from a sheet material and heated up to a quenching temperature is subjected to a press forming step while being held in position by means of die members providing in combination the final space configuration of a desired product, thereby transmitting heat from the stock to the die members for quenching the stock simultaneously with the press-forming thereof to its final configuration.

Next, referring to FIGS. 3 and 4, a preferred apparatus adapted for carrying out the process will be described in detail.

In these figures, the numeral 10 denotes a bed which is provided with a plurality of legs 11 mounted in position on a floor surface 12. A plurality of vertical columns 13 are rigidly attached with their lower ends to the bed 10 and a rigid top plate 14 is fixedly attached to the upper ends of said columns. A hydraulic cylinder 15 is rigidly mounted on the plate 14 although the fixing and attaching means have been omitted from the drawing on account of its very popularity. The interior cylinder spaces 22 and 23 defined by a piston 24 slidably received in the cylinder 15 are connected through respective pipings 16 and 17 and a control valve assembly 18 to a certain conventional hydraulic pressure source, such as pressure oil reservoir, oil pump or the like, not shown. Control valve 18 is so designed and arranged as to be manipulating a control lever 19 attached thereto, pressure oil flow through these pipings 16; 17 can be on-off controlled for supply and discharge of oil to and from the cylinder 15.

A slide or ram 20 formed into a horizontally extending rigid plate is formed with a plurality of tubular members 21 which are slidably mounted on said columns 13.

The hydraulic cylinder 15 is provided with an upper cover flange 15a and a lower cover flange 15b rigidly attached by means of a plurality of fixing bolts, not shown only for simplicity of the drawing, for sealing through suitably designed and arranged conventional gasket means, not shown, the cylinder spaces 22 and 23, and removing the top plate 14 which is rigidly connected with a vertically extending piston rod 25 which is in turn rigidly connected at its lower extremity with the ram 20, although the fixing means have not been shown only for simplicity. Therefore, the assembly comprising piston 24, rod 25 and ram 20 is slidable movable in the vertical direction, as hinted by a small double head arrow 25a shown in FIG. 3 by pressurizing the hydraulic working liquid medium such as oil prevailing in the upper or lower cylinder chamber 22 or 23 by properly manipulating the control valve 18 as conventionally.

A holder plate 26 is fixedly attached by means of a plurality of fixing screws 27 on the bottom surface of the ram 20, and carries an upper die element 28 rigidly attached by means of fixing screws 29 to the holder 26, said die element being shaped into substantially a stepped hollow cylinder. The die member 28 is formed in the bottom wall with a positioning recess 129 which is so designed and arranged to cooperate with a mating pin 30, as will be more fully described herein. The interior space 26a is provided with a plurality of fixing bolts 33 to a shoulder surface 34 formed on a upper part of the die member 28. The bottom surface 28a around said positioning recess 129 is shaped into a tapered ring surface adapted to shape the inside truncated cone surface of the product diaphragm spring 40. The thus sealingly closed interior space 26a of the upper die member serves as a cooling liquid space wherein a coolant, preferably cold water, is supplied through a flexible tubing 43 and let out through a duct 133 bored laterally through the upper part of the die wall, a flexible tubing 34 connected at its one end fixedly to said duct 133; and a piping 35 connected rigidly with the opposite end of said tubing 34.

A lower holder plate 36 which is similar in its design and function with the upper holder plate 26, is fixedly attached by screws 37 to the base or bed 10, on its upper surface 36a as shown more specifically in FIG. 4, said plate 36 mounting in turn fixedly by means of a plurality of fixing screws 39 a lower die member 38 which is shaped substantially into an inverted conical cylinder cup, the interior inside space 36a being sealingly closed by a closure plate 49 similar to the upper closure 31. This plate 49 is fixedly attached through the intermediary of a seal ring 44 by set screws 48, the thus sealingly closed interior space 36a serving again as a cooling liquid chamber as in the case of upper die chamber 28a. The upper or working surface 36b of the lower die member 36 has a general configuration mating with that 28b of the upper die member 28 and is formed with a central recess 136a which receives snugly the positioning or centering round pin 30 for a processing work piece 40, the latter being formed with a central opening 40a for slidably receiving said pin.

The lower die member is formed with a duct 134 which is bored through the lower part of the peripheral wall of the die 36 to which is fixedly attached a coolant supply piping 42 leading to a supply source, not shown. A control valve 45 is inserted in this piping 42 for control of proper supply quantity of the coolant which is preferably cold water. Both cooling chambers 28a and 36a are kept in fluid communication with each other by means of a flexible tubing 43 which is connected at its respective ends with said chambers, as most clearly seen from FIG. 4.

In the following, a process for the simultaneous press-forming and quenching operation according to the invention will be described in detail, in conjunction with the operation of the press so far shown and described with reference to FIGS. 3 and 4.

The processing stock 40 or diaphragm spring stock, had an outside diameter of 170 mm and a thickness of 2 mm. The material of the stock was carbon tool steel, class 5 (JIS, SK-5), while that of the dies 28 and 36 was structural carbon steel (JIS, S45C). The term "JIS" is an abbreviation of "Japanese Industrial Standard."

The flat diaphragm spring stock was heated in a suitable furnace or the like at a austenitizing temperature of about 830°C; promptly taken out from the furnace and then placed on the lower die 36 with its positioning pin 30 brought into registration with the central round opening 40 of the stock 40. Next, the control valve 18 is actuated so as to introduce the pressurized working liquid through the piping 16 into the upper cylinder space 22 for forcibly lowering the ram assembly comprising piston 24, rod 25, ram plate 20, upper holder plate 26 and upper die 28, towards the lower die 36, thereby bringing the stock into its squeezed position between the both die members under high pressure. At this pressing and quenching stage, the upper surface of the stock is brought into pressure contact with the working surface of the upper die and in the similar way the bottom surface of the stock is brought into pressure contact with the working surface of the lower die. In this way, the stock is forcibly transformed from its plane configuration into the final or substantially truncated cone shape shown in FIG. 2. At the same time, surplus of heat is discharged from the stock and penetrates through the walls of the respective working parts into the circulating cooling medium, preferably cold water and was carried along thereby. In this way, the stock was press-formed to the desired shape and at the same time quenched in an effective manner.

The die-application pressure acting upon the stock may be varied from about 6 to 2,000 kgs. per sq. cm according to the size and dimensions of the stock to be treated. Therefore, the
forming and quenching press may be of a considerably large size so as to process even a large size product. All the practical tests have showed amazingly favorable results for attaining the combined press-forming and quenching effect.

Next, referring to the charts shown in FIGS. 5 and 6, the way for selecting proper kind of material and the necessary heat capacity for the cooling tools depending upon the kind of material and size or thermal capacity of the treating stock will be considered from the several experimental results. It may be naturally conceivable that with increase of the thermal penetration rate of the pressing and quenching dies, the higher cooling rate of the treating stock must be expected. Next, it should be noted that the temperature, $T_s$ as observed at the contacting surface which is deemed to establish at an instant when two bodies having different temperatures are brought into physical contact with each other, can be determined by the following formula:

$$ T = \frac{T_s \cdot b + T_b \cdot b}{b + b_s} $$

where $T_s$ and $b$ represent the initial temperature and thermal penetration rate of one body, respectively; and $T_b$ and $b_s$ stand for those of the other body, respectively.

As an example, consider such a case where a treating stock of carbon steel, heated up to 800°C. ($= T_s$) is to be quenched. In this case, what kind of material and what rate of thermal penetration should be selected for the quenching dies? Then, the following calculation can be performed:

The thermal penetration rate ($b$) for carbon steel may be safely taken as about 200 Kcal/m²·°C·h$^{1/2}$ and the temperature ($T_b$) of the cooling tool means may be assumed to be 20°C. If the stock is quenched beyond the perlitic transformation temperature of steel (which means the nose temperature on S-curve of steel), about 500°C. ($= T_b$), instantly upon contact of the steel with the quenching tool, the desired quench effect may definitely be introduced. When these values are introduced in the above formula 1, then:

$$ b_{125} = \frac{125 (Kcal/m²·°C·h^{1/2})}{200} $$

Thus, the tool material having larger value of thermal penetration rate than the above calculated value of $b_s$ will serve for the desired purpose. From observing the chart shown in FIG. 5, it will be seen that copper, silver and iron have larger thermal penetration values than that above specified. Thus, it can be concluded that any one of the above specified several metals will serve well for the quenching purpose. In the above calculation, however, thermal resistance between the contacting surfaces and the hardenability of the kind of alloy have been neglected. In fact, however, it can not be always said that the quenching effect is introduced depending exclusively upon the surface temperature of the treating stock upon contact with the quenching tool, wherein the above kind of contacting thermal resistance, the hardenability of the treating stock and the size or thermal capacity of the treating stock must be necessarily taken into account. In FIG. 5, experimental results are shown, illustrative of the relationship of the thermal penetration rate $b$ and the hardenability (represented by ideal critical diameter : $D_i$, with larger value of this diameter, the hardenability will be correspondingly high) relative to the size of the treating stock.

On the chart shown in FIG. 5, the curve (A) shows the relationship between the necessary heat penetration rate (several representative materials being specified in their order of thermal penetration rate along the axis of ordinates) and the kind of material in case of quenching treatment of a steel plate having 2 mm thickness. As an example, when a plate made of JIS, S45C (D, nearly equal to 0.8 in; thickness being 2 mm) is to be quenched, the thermal penetration rate of the cooling die may be determined as:

$$ b = 200 $$

by observing said curve (A).

Thus, when quenching a plate made of this kind of steel and having a thickness of 2 mm, the value of heat penetration rate higher than 200 will suffice for the desired purpose and the quenching material may be Fe, Al or Cu. It will be seen that in this case, the desired quenching can be realized by adopting any selected combination from the area above the curve (A). In the similar way, the area above the curve (B) shows various combinations for allowing a quenching of steel plate, 6 mm thick. The area above the curve (C) shows the similar way various combinations for allowing a quenching treatment of a 25 mm-thick steel plate. Non-ferrous material such as aluminum shows a similar tendency as above specified.

As for the thermal capacity (specific heat multiplied by weight), Kcal/°C, the quenching may be more easily carried into effect with higher value thereof owned by the cooling material than that of the treating stock.

The attainable final temperature $T_f$ (°C.) of the treated stock can be calculated from the following formula:

$$ T = \frac{C_i - T_i + C_s - T_s}{C_i + C_s} $$

where, $C_i$ stands for the necessary minimum thermal capacity of the treating stock;

$T_i$ represents the initial temperature of the stock;

$T_s$ stands for the initial temperature of the cooling material;

and $C_s$ represents the thermal capacity of the same material.

When considering a representative case wherein a steel stock is quenched by contact with a solid cooling material, the theoretically attainable final temperature of the stock upon contact with the quenching material must be lower than the transformation starting temperature of martensite, or Ms point. In the case of quench treatment of a steel having a Ms point of 200°C. ($= T_s$), from a temperature of 800°C. ($= T_i$), and assuming that the temperature of the stock to be quenched is at 20°C. ($= T_b$), the ratio $C_i/C_s$ will be nearly equal to 3.3 when introducing these values into the above formula (2). In order to bring the temperature of the stock by a quenching contact of the above nature, to a value lower than Ms point, the thermal capacity of the quenching material must be at least 3.3 times that of the treating stock. When the attainable final temperature of the stock is plotted against the relative ratio between the thermal capacity of the stock and that of the quenching material, a curve will be obtained as shown, by way of example, in FIG. 6. Ms points for several preferred materials are also shown along the abscissa ordinates.

In the following, several specific features will be described based upon the practical experiments. In these experiments, the forming and quenching tools were of structural carbon steel, JIS, S45C.

In FIG. 7 several comparative curves are shown. The stock materials were JIS, S45C and JIS, SCM 4, the latter being chromium-molybdenum steel, class 4. When the quenched hardness is set to HRC 55, the hardenable thickness of steel plate stock amounted to similar or even higher value than those obtainable with the conventional oil quenching process. In the comparative tests shown in FIG. 7, samples were quenched from 850°C. by the process according to this invention, and comparison is made with the oil quenched results. The quenched hardness was plotted against the thickness of the sample. It will be seen from the chart, about 8 mm thick samples of JIS, S45C and those about 16 mm thick of JIS, SCM 4 could be effectively quenched according to this invention.

As seen from a further chart shown in FIG. 8, a considerably wide range of die applying pressure can be employed in the practice of the inductive quenching process for realizing an evenly distributed quench hardness and a specific thickness of the sample which was in this case a diaphragm spring for automotive clutch use, as was already referred to heretofore.
In this chart, the quenched hardness was plotted against the die-applying pressure. At the right-hand side and along the axis of ordinates, the final thicknesses of the quenched samples are shown.

As seen, the die-applying pressure necessary for obtaining an even distribution of quenched hardness amounts to 6 kgs. per sq. cm. or higher. On the other hand, the die-applying pressure necessary for providing an even thickness of the quenched steel sheet stock ranges from nil to 2,000 kgs. per sq. cm. which means a considerably wide range. It is naturally recommendable to adopt, out of the above specified pressure range, a possible minimum, yet enough large pressure for attaining the desired press-forming effect of the processed work piece. If, however, a reduction in the thickness of the steel sheet stock during the press-forming and quenching process is allowable to a certain degree, or alternatively a reduction in the thickness of the processing stock is desired rather in a positive way, the die-applying pressure range above specified would have a minor importance.

In the following table, a comparative test result is shown in terms of the difference in lever end height as a measure of developed quench distortion in the quenched steel products, more specifically diaphragm springs for automotive clutch use, which have been processed comparatively according to the prior art oil quenching process and the press-forming and quenching process proposed by the invention. It has been found that the product processed in accordance with the invention represents only one-eighth – one-fourth those encountered with conventional quenching processes.

<table>
<thead>
<tr>
<th>Kind of quenching Process</th>
<th>Irregularity in Height at Outside Periphery</th>
<th>Irregularity in Height at Inner Lever Ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional (Oil Quenching)</td>
<td>1.12 mm.</td>
<td>3.61 mm.</td>
</tr>
<tr>
<td>Invention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Press-forming and Quenching</td>
<td>0.14 mm.</td>
<td>0.25 mm.</td>
</tr>
</tbody>
</table>

Remarks: the above figures were taken as the mean values of 50 test samples in each case.

The irregularity in height at outside periphery of the product as specified above was measured in such a way that the product diaphragm spring was placed on a surface plate and the local gaps between the peripheral bottom surface of the diaphragm and the surface plate were precisely measured. When the gap was measured to nil, it was assumed that there was no quench distortion. On the other hand, the irregularity in height at inner lever ends was determined by the difference in height between the highest lever end and the lowest lever end. When the difference be nil, the quench distortion in this respect was assumed also to be nil.

In the following, we will compare the inventive process with the conventional process in relation to the thermal cycle. The comparative conventional process comprises the following four processing steps in succession:

- press-forming a plane diaphragm spring stock so as to the desired truncated cone shape;
- heating the press-formed stock at about 830°C for about 20 minutes and immersing it in an oil bath for quenching;
- heating the quenched stock at about 320°C for about 90 minutes and then air-cooling it to normal temperature, for reducing the hardness to a certain small degree; and
- heating the thus treated stock while forcibly kept in position by applying jig means thereon, to about 450°C for about 180 minutes and then air-cooled to normal temperature for tempering to relieve of quenching distortion.

According to the quenching process proposed by the invention, the plane stock is heated at about 830°C for about 20 minutes and then squeezed between a pair of press-forming dies for quenching as well as press-forming the stock. The thus quenched and press-formed stock represents only a smallest possible quench distortion, as was enlisted, by way of example, in the foregoing table, thus practically obviating an additional and separate distortion-relieving step normally and conventionally employed. It is only necessary to heat the quenched stock at about 450°C for about 90 minutes and then air-cooled to normal temperature, for attaining a tempering effect, thereby the whole process consisting of only two heat-treating steps and improving the overall thermal efficiency.

According to our practical experiments, it has been found that the novel teaching proposed by the invention may be carried into effect in such a way that the steel stock is press-formed and at the same time locally quenched.

A modified embodiment of the process as well as the apparatus according to this invention will be described by reference to FIGS. 9 and 10.

In this case, a diaphragm spring stock 40 destined for automotive clutch use and prefabricated from a steel sheet, 2 mm thick, the material steel being carbon tool steel, Class 5, in conformity to the specifications of JIS, SK-5 as before, was processed on a modified machine shown in FIG. 9. The processing was so carried out that it was press-formed to the desired final shape of a truncated cone in its elevated configuration, while at the same time the stock is subjected only locally at the peripheral ring-shaped area 101 (FIG. 2) as defined therein by an imaginary dotted circle 104, and extending outwardly therefrom.

For this purpose, the lower and lower die elements 28 and 36 are formed with respective mating working surfaces 28b and 36b having more limited areas than before adapted for performing the desired local quenching from both upper and lower sides of the peripheral ring-shaped zone of the stock, the remaining working surface of each of said dies being substantially recessed at 28d or 36d, respectively, for avoiding the stock from any physical contact with the press dies.

The processing particulars in this case were same as before. More specifically, the diaphragm spring stock 40 was heated to a quenching temperature as before and then placed on the lower die element 36' around its centering pin 30' and the upper die element 28' was lowered hydraulically as before against the lower die element through the intermediary of the thus centrally positioned processing stock. Naturally, in this case, the outer ring peripheral zone 101 of the stock was brought into heat-conducting pressure contact with the respective working surfaces 28b and 36b, the remaining area of the stock being prevented from contact with the press and quenching die elements, as was briefly described hereinafore. In FIG. 9, the thus contacted ring are 101' being shown as "x", while the remaining non-contacting working zone being denoted by "y". In this way, the contacted and pressureized area "y" was only quenched, while the remaining non-contacting area "x" was subjected in noway to the quenching effect.

FIG. 10 represents a curve showing a distribution of the hardness after quenching in the thus treated stock. As clearly seen from this curve, the outer peripheral zone 101' of the stock 40', said zone having a radial length "y" as said above, is subjected to a substantial quenching amounting to about Hv C 65°, while the remaining non-contacted area, having a radial length of "x", has not been quenched, representing in the mean a hardness of about Hv C 30°. The temperature from which the stock was quenched was 830°C as mentioned hereinbefore.

In this way, the stock was press-formed and at the same time effectively quenched.

From the foregoing, it may well be understood that the process according to this invention provides a combined press-forming and quenching effect, whether wholly or locally as the case may be, and with a minimum possible quench deformation, so that otherwise necessary press-tempering step for relieving the appreciable deformation developed in the quenching step may be substantially obviated.
In addition, the hardness distribution in the quenched stock is highly even and advantageous when relying upon the novel teaching proposed by the invention.

Under circumstances, the die elements and/or the treating stock may be surface-treated for accelerating or decelerating the quenching effect. For the same purpose, liquid or pulverized medium may be applied onto the working surfaces of the die elements, or even onto the processing surface of the stock per se. An insertion of a metal foil between the working piece and the working surface of the die element. For attaining a more effecting cooling function provided by the coolant, the latter may naturally be pre-cooled in advance of introduction thereof into the die cooling spaces. A cooling brine may be used under certain occasions.

What we claim is:

1. A process for press-forming and quenching a diaphragm spring made of steel stock, comprising the steps of:
   a. heating the diaphragm spring to its austenitizing temperature;
   b. placing the heated diaphragm spring on one of two mutually cooperating die members;
   c. cooling said cooperating die members with a liquid cooling medium; and
   d. pressing said heated diaphragm spring between the pair of mutually cooperating die members at a pressure of 6-2,000 kgs./sq.cm. while rapidly removing considerable heat from the diaphragm spring through thermal conduction and penetration therefrom to said die members, to form said diaphragm spring to its desired shape while simultaneously providing a quench and hardening effect upon the diaphragm spring stock.

2. The process as claimed in claim 1, wherein said diaphragm spring is heated to a temperature ranging from 750° C. to 950° C. and is simultaneously pressed and quenched to harden said diaphragm spring to a hardness of HRC 55.

3. The process as claimed in claim 1, further comprising the step of partially pressing the diaphragm spring under pressure between the pair of said die members to partially press-form the diaphragm spring to its desired shape while partially removing considerable heat rapidly from a peripheral ring-shaped spring part of the diaphragm spring through thermal conduction and penetration therefrom to said die members for quenching and hardening said part of the diaphragm spring.

4. An apparatus for simultaneously press-forming and quenching a diaphragm spring made of a steel stock, comprising, an upper die element having a working surface thereon for registration with the corresponding finished surface of the diaphragm spring, a lower die element cooperating with said upper die element and having a working surface for registration with the corresponding opposite finished surface of the diaphragm spring, each of said upper and lower die elements having an interior space formed therein through which a liquid coolant is subjected to a rapid cooling for quenching and hardening said spring to a predetermined hardness simultaneously with a power actuating means operatively connected to said die elements for moving said die elements towards and away from each other for applying a mechanical pressure of 6-2,000 kgs./sq.cm. on said diaphragm spring stock when said diaphragm spring is pressed between said die elements upon actuation of said power actuating means to move said die elements towards each other, said conduit means operatively connected to the interior space in said upper and lower die elements for supplying and discharging said liquid coolant to and from the interior space of each of said die elements, whereby said diaphragm spring stock is subjected to a rapid cooling for quenching said spring simultaneously with the pressing of said spring to form said spring to its desired shape under pressure between said cooled die elements.

5. An apparatus as claimed in claim 4, characterized by each of said cooperating die elements being formed with a recess partially defining said working surface for obtaining the desired local quenching effect upon the diaphragm spring being pressed therebetween.

6. An apparatus as claimed in claim 4, wherein said liquid coolant is cold water.

7. An apparatus as claimed in claim 4, wherein one of said conduit means is connected between the interior spaces of said upper and lower die elements for conducting coolants therebetween.

8. An apparatus as claimed in claim 4, wherein said lower die element further comprises a positioning pin located in the center thereof for guiding and positioning a central circular opening formed in said diaphragm spring, and said upper die element is formed with a corresponding positioning recess for cooperation with said pin when said die elements are moved towards each other.

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