METHOD OF MAKING BALL STUDS

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FOREIGN PATENTS OR APPLICATIONS

FOREIGN PATENTS OR APPLICATIONS
15,548 10/1969 Japan........................................ 287/90 R

OTHER PUBLICATIONS

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ABSTRACT
A method of making a ball stud in which a low carbon steel or a low carbon alloy steel is used as a starting material, the material is coldly formed into the ball stud, a lower carbon content and smaller carburization depth are selected in comparison with an ordinary carburization method and diffusion heat treatment of said material is carried out at substantially the same temperature as the carburization temperature, then said material is subjected to quenching and tempering treatment and finally induction hardening is applied only to the ball portion of said ball stud.

11 Claims, 6 Drawing Figures
Fig. 1

![Graph showing temperature changes over time.](image)

Fig. 2a

![Diagram of a mechanical component.](image)
Fig. 2b

DEFLECTION AT THE CENTER OF BALL (mm) vs. BENDING LOAD APPLIED TOWARD THE CENTER OF BALL (kg)

Fig. 2c

DEFLECTION AT THE CENTER OF BALL (mm) vs. IMPACT ENERGY (kg·cm)
Fig. 3

A: HARDNESS DISTRIBUTION OF BALL PORTION

A': HARDNESS DISTRIBUTION OF STEM, TAPERED PORTIONS AND SHANK
Fig. 4

![Graph showing deformation resistance and work done against deformation ratio. The graph includes two curves labeled $K_f$ and $\omega$.](image-url)
3,885,996

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METHOD OF MAKING BALL STUDS

CROSS-REFERENCES TO RELATED APPLICATIONS

This invention is a continuation-in-part of application of Ser. No. 210799 filed Dec. 22, 1971, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the invention

This invention relates to a method for heat treating ball studs to be used for steering or suspension mechanism of the automobile and, more particularly, to a heat treatment process of a ball stud, which is coldly worked from low carbon steel or low carbon alloy steel through punch and die extrusion techniques.

2. Summary of the invention

An object of this invention is to provide an improved heat treatment by which high resistance to fatigue is given to the ball stud under various loading conditions such as multi-directional and complicated impacts, vibration etc.

Another object of this invention is to provide a method of manufacturing a ball stud which uses a low carbon steel or a low carbon alloy steel having excellent cold formability as the starting material.

It is a further object of this invention to provide a method for manufacturing a ball stud which is made by punch and die extrusion techniques, is finished by roller burnishing and gives a better finish.

It is another object of this invention to provide a method of manufacturing a ball stud which reduces the cost of cold forming and extends the life of tools used for cold forming.

The method comprises the steps of providing carbon steel containing from 0.13 to 0.18 percent of carbon, 0.15 to 0.35 percent of silicon, 0.60 to 0.85 percent of manganese, 0.9 to 1.2 percent of chromium, less than 0.30 percent of nickel, 0.15 to 0.30 percent of molybdenum and remainder substantially all iron; cold forming the carbon steel into a ball stud; carburizing the whole surface of the ball stud; diffusing the whole surface of the ball stud; quenching the ball stud; tempering the ball stud; high frequency induction heating is restricted to the ball portion only of the ball stud and quenching is restricted to the ball portion only of said ball; whereby the metallic structure of the surface of the ball portion consists of martensite and the inner portion of the ball portion consists of sorbite, bainite and ferrite, that of the surface layer of the shank and threaded portions consists of sorbite and that of the inner portion thereof consists of sorbite, bainite and a minor amount of ferrite.

The above and other objects and attendant advantage of this invention will be more readily apparent to those skilled in the art from a reading of the following detailed description referring to the accompanying drawings which show preferred embodiment of the invention for illustration purpose only, but not for limiting the scope of the invention in any way.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a time-temperature transformation diagram illustrating heat treatment process for a ball stud of this invention.

FIG. 2a is a schematic diagram showing a hollow type ball stud and a testing device therefor.

FIG. 2b shows test result of the loading test by the testing device shown in FIG. 2a in which the longitudinal axis shows bending load given to the central portion of the ball and the transversal axis shows flexure at the center of the ball of the ball stud.

FIG. 2c shows the same as in FIG. 2b, in which the longitudinal axis corresponds to absorption energy and the transversal axis corresponds to flexure at the center of the ball.

FIG. 3 shows hardness distribution in the hardened layer of the ball portion of the ball stud, and

FIG. 4 shows deformation ratio versus deformation work relationships and deformation ratio versus deformation resistance relationships in which Kf, w are respectively deformation resistance and deformation work done on the ball stud material in accordance with this invention.

PREFERRED EMBODIMENTS OF THE INVENTION

The present invention will now be described referring to the accompanying drawings and more particularly, to FIGS. 1 and 2a thereof.

In the first place, a case hardened steel, for example low carbon steel containing 0.15 percent of carbon, 0.9 percent of chromium, and 0.20 percent of molybdenum as main components is provided as the starting material for manufacturing the ball stud of the present invention.

The starting material is heat treated in order to produce a globular form of carbide and is supplied in the form of a round bar, straight or coiled.

In the second place, as shown in FIG. 2a, the coiled round bar is formed at room temperature into a hollow type ball stud (hereinafter referred to as a blank) applying cold forming, for example the manufacturing method described in the U.S. Pat. No. 3,553,826 patented Jan. 12, 1971. The hollow type ball stud 10 as produced in accordance with this invention comprises a threaded stem 11, tapered portions 12 and 13, shank 14 and head portion or ball portion 15. The head portion 15 is generally circular in cross-section, as shown, and the interior thereof is provided with a substantially spherical cavity 16 connecting with an opened passage 17 located in generally the center of the head portion.

In accordance with the time-temperature transformation diagram shown in FIG. 1 of the present invention, the ball stud 10 is heated up along a line O-A-B-C to an appropriate temperature between 890°C and 920°C selected corresponding to the carbon content of the blank, in a carburizing furnace filled with a carrier gas having a dew point of +10°C. At an appropriate temperature between 800°C and 850°C (designated point A in FIG. 1) in the heating up process of the blank, enriched gas is supplied to the heating furnace as an enriching gas in order to increase the carbon content of the surface layer of the blank keeping the dew point temperature of the atmosphere gas in the range between +5°C and -30°C. The blank is kept within the temperature range of from 890°C to 920°C for a period which is adjusted according to the desired depth of the carburization of the blank, for example about one hour for carburization to a depth of about 0.5mm. The supply of the enriched gas is stopped at point C and then the blank is subjected to the diffusion carburization treatment at the above temperature. A time interval
C-D of the diffusion carburization treatment is the last one third of the time interval B-C of the gas carburization at the above temperature as shown in FIG. 1. After the completion of the diffusion treatment process (at a point D), the blank is immediately quenched in an oil bath held at a temperature of, for example, 50°C. After this heat treatment, the surface microstructure of the blank consists of martensite with 0.60 percent carbon content, and the inner microstructure of the blank consists of a greater amount of martensite and a small amount of bainite and ferrite. The surface carbon content of the blank is thus suitable for being readily regulated by the control of the dew point of the atmosphere gas in the gas carburization process. Such microstructure of the inner portion of the blank (uncarburized portion) is quite satisfactory as a quenched structure for the steel used as the starting material of this invention.

Sequentially, the blank is heated up along line E-F and, as shown by line F-G in FIG. 1, is tempered within a temperature range of from 420°C to 500°C immediately after the gas carburization and first quenching treatment processes. That is, at fixed intervals of time, for example, about 90 minutes, the blank is kept within the temperature range. After that, the blank is subjected to cooking along a line G-H. The microstructure obtained after the primary tempering treatment is composed of sorbite in the carburized surface layer, while the inner portion thereof is composed of sorbite and a minor amount of bainite and ferrite. Thus, excellent mechanical properties and an improved toughness are given to the ball stud of this invention.

Next, the surface of the ball portion only of the completely tempered blank is further subjected to high frequency induction hardening. That is, the surface of the ball portion of the blank is heated up by electromagnetic induction along a line H-I-J of FIG. 1 and is immediately heated to a temperature within the range of from 800°C to 850°C. In the high frequency induction heating, the heating time required for the surface of the ball portion is about 1 second to 2 seconds. After that, along a line J-K shown in FIG. 1, the ball portion of the blank is immediately quenched in the quenching medium, for example, water, conventional quenching oil or soluble oil. In this third quenching treatment, the quenching depth is in the range of about 0.6mm to 0.8mm, and a tempering treatment at a relatively lower temperature range, such as from 150°C to 200°C is carried out, if necessary. In the third tempering treatment, the blank is kept for about 60 minutes at an appropriate temperature within the temperature range just stated.

The mechanical properties and other features of the ball stud manufactured by the method of this invention are shown in Table 1. The shape of the ball stud used in this test has the given-mentioned dimensions.

Referring now to FIG. 2a, a load is applied to the center of the ball 15 of the ball stud 10 in the direction shown by arrow P. In the test, the ball stud 10 is secured to the jig 20 by the nut 21 for achieving the loading tests shown as item 6, 7 and 8 of Table 1. P shows the directions of bending, falling impact and bending fatigue loads. The test results shown in Table 1 are based upon tests carried out over three years from 1967 to 1969. By way of example the approximate dimensions of a stud as disclosed in FIG. 2a may be, in millimeters: D - 26; d - 14.46; L - 54; length 1 - 22.4.

On the other hand, the results of the loading tests are shown in FIGS. 2b and 2c. FIG. 2b shows bending load given to the central portion of the ball 15 versus flexure and FIG. 2c shows absorption energy versus flexure at the center portion of the ball 15. According to these test results, the ball stud 10 obtained by the heat treatment of this invention has excellent resistance to impact load, strength and ductility. It should be noted that, in the bending test of the ball stud 10, no crack was observed with respect to the ball stud 10 of this invention as shown in FIG. 2b.

FIG. 3 shows hardness distribution of the ball 15 of the completed ball stud 10 in which hardness changes from the surface of the ball are illustrated in connection with the distance from the surface of the ball portion. In the drawing, the curve A shows the hardness distribution of the ball portion 15 quenched by high frequency induction heating method in accordance with this invention and the curve A' shows, for reference, a hardness distribution of the threaded stem 11, tapered portions 12 and 13 and shank 14 which are not subjected to the high frequency induction heating method in accordance with this invention.

As is readily understood from these hardness distribution curves, superior hardness distribution in the surface layer of the ball portion is obtained by the additional high frequency induction heating and subsequent quenching, of this invention, in spite of less carburization concentration and depth thereof.

In FIG. 3 the value of the longitudinal axis and of the lateral axis show the hardness according to Rockwell C Scale and the depth from the surface layer (mm) respectively, and gradation between the hardened surface layer and the inner portion is smooth, hence showing the remarkable advantages of the carburization and high frequency heating treatment in accordance with this invention.

As described above, since the carbon steel containing from 0.13 to 0.18 percent of carbon and having an excellent workability at room temperature, is used as a starting material in the method of this invention, the life of the punch and die made of a high speed steel and used for hollowing out the hollow type ball stud, can be remarkably extended. The curves shown in FIG. 4 illustrate deformation resistance, the relationships between the deformation work done and the deformation ratio, in which Kf corresponds to the deformation resistance (K/mm²) of the steel containing 0.15 percent of carbon, 0.9 percent of chromium and 0.20 percent of molybdenum as main components, while w corresponds to the deformation work done (mm - Kg/mm²) of the steel. Accordingly, the longitudinal axis shows Kg/mm² and mm - Kg/mm² and the lateral axis shows the deformation ratio (percent) of the steel used. As is readily understood from the drawing, the low carbon steel usable for working this invention is 15 to 20 percent lower in either deformation resistance or in deformation work done than the middle carbon alloy steel containing from 0.4 to 0.6 percent of carbon which is used as a starting material of a ball stud in the prior art manufacturing processes. This is remarkably advantageous for extending the life of the tools used. For example, a punching tool made of high speed steel used for hollowing out a hollow type ball stud can, in case of giving a deformation ratio of 60 percent, works about 10,000 to 20,000 pieces of the low carbon steel in contrast to only about 2,000 to 5,000 pieces of the middle carbon
steel. By the way, it is well known that a minor difference in the deformation resistance or flow stress in the steel or alloys to be worked has, especially in case of working with high deformation ratio, a remarkable effect on the life of the tool and manufacturing efficiency, as mentioned above.

To summarize, the essentials of this invention are as in the following.

First, according to the present invention, a low carbon steel or a low carbon alloy steel having excellent cold-formability at room temperature is used as the starting material so that the forming process at room temperature can be more readily and effectively achieved.

Second, the low carbon steel or the low carbon alloy steel having small deformation resistance or enabling a large amount of deformation work to be done is used as the starting material so that the life of the punch and die tool used for hollowing out the hollow type ball stud can be remarkably extended.

Third, a low carbon steel or a low carbon alloy steel is used as the starting material and carburization, diffusion, quenching and higher temperature tempering treatment are applied to the ball stud so that a ball stud having the characteristics of middle carbon alloy steel in the surface layer and of low carbon steel in the inner portion of the ball stud can be manufactured. The tempering treatment is carried out at the higher tempering temperature rather than those used for an ordinary carbon steel so that the mechanical properties, such as toughness or ductility, fatigue limit, tensile strength, resistance to the impact, bending load etc. can be remarkably increased.

Forth, the induction hardening treatment is applied to only the ball portion of the ball stud whereby a ball stud having an excellent wear-resistance can be manufactured in spite of its relatively slight carburization depth of about 0.3 to 0.5mm from the surface and low carburization carbon content, such as about 0.6 percent, of the surface carburizing layer.

Fifth, the low carbon steel or the low carbon alloy steel is used as the starting material so that a ball stud having a better finish can be manufactured only by roller burnishing without need for grinding, lapping etc. can be manufactured.

Finally, the method of manufacturing the ball stud of this invention can be used with a low capacity working press, since a low carbon steel or a low carbon alloy steel is used as the starting material of the ball stud. In addition, when the method of this invention is used for manufacturing ball studs less time is required for the manufacturing process and the manufacturing cost is reduced remarkably. This heat treatment process in accordance with the present invention can also be used in the manufacturing of an article or part which requires wear resistance for a restricted part of said article or part and simultaneously special toughness and strength for the remaining part of said article, such as valve lifter, valve adjusting screw etc. used in the internal combustion engine.

While there is described above the principles of this invention in connection with specific process for heat treatment, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of this invention.

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**Table 1**

<table>
<thead>
<tr>
<th>Material composition (Main components) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Carbon Steel Carbon: 0.15, Chromium: 0.9, Molybdenum: 0.20</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Treatment processes after cold forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carburetion quenching (890°C) + Primary tempering (420°C) + Induction hardening (800°C) + Tempering at low temperature (160°C)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tensile strength of the screw thread portion (σB: kg/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 – 130</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Proof stress of the screw thread (σS: kg/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 – 120</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Tensile strength of the shank portion (σB: kg/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 – 120</td>
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</table>

<table>
<thead>
<tr>
<th>Proof stress of the shank portion (σS: kg/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 – 90</td>
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</table>

<table>
<thead>
<tr>
<th>Hardness of the inner portion (HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 – 40</td>
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</table>

<table>
<thead>
<tr>
<th>Bending fatigue strength (Preax: before the generation of crack: 1,000kg cycle, Prmm: 100kg)</th>
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</thead>
<tbody>
<tr>
<td>2,700kg or more</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Falling impact strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height from which a weight of 30kg is dropped onto the ball portion before generating a crack (mm)</td>
</tr>
<tr>
<td>1,200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Falling impact strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height from which a weight of 30kg is dropped onto the large crack (mm)</td>
</tr>
<tr>
<td>71,500</td>
</tr>
</tbody>
</table>
What is claimed is:

1. The method of making a ball stud from a rod-like blank initially containing as essential ingredients 0.13 to 0.18 percent carbon; 0.9 to 1.2 percent chromium, 0.15 to 0.30 percent molybdenum, and the remainder essentially all iron; cold forming one end of the blank into a ball portion; heating the blank to about 800°C, then supplying carburizing gas to the blank while raising the temperature thereof in the range 890°C to 920°C, cutting off the supply of carburizing gas at the end of a preselected time period, while maintaining the temperature essentially constant in the aforesaid range for a time about one-third of said preselected time period, to effect diffusion, quenching the blank, reheating the blank in the range 420°C to 500°C, for about 1/2 hours, quenching the blank, rapidly reheating the ball portion only of the stud by high frequency induction in the range 800°C to 850°C, and immediately quenching the reheated ball portion.

2. The method of claim 1, the carbon content of the surface layer of the ball portion being from 0.5 to 0.7 percent and essentially martensite, after induction heating and quenching.

3. The method of claim 1, the depth of carburization of the ball portion being between about 0.3 and 0.6 mm, on completion.

4. The method of claim 1, the steel forming the blank also containing as contaminants and/or non-essential ingredients, 0.15 to 0.35 percent silicon, 0.60 to 0.85 percent manganese, and less than 0.30 percent nickel.

5. The method of claim 1, said preselected time period being about one hour to effect carburization to a depth of about 0.5 mm.

6. The method of claim 1, and subsequent to quenching the reheated ball portion, raising the temperature of the blank to the range 150°C to 200°C, for about one hour.

7. The method of claim 1, and regulating the dew point of the carburizing gas, during carburization, to correspondingly control the carbon content of the surface layer of the blank.

8. The method of claim 7, said carburizing gas being regulated to have a dew point in the range +5°C and -3°C during carburization in the range 890°C to 920°C, as aforesaid.

9. The method of claim 1, the reheating of the ball portion only of the blank by induction, being effected in about 1 to 2 seconds.

10. The method of claim 1, and controlling the carbon content of the surface layer of the blank by (a) regulating the dew point of the carburizing gas during carburization; and (b) varying the depth of carburization of the surface layer by correspondingly varying the time of carburization.

11. The method of claim 1, said preselected time period being about one hour for a carburized surface layer of depth about 0.5 mm, while controlling the carbon content thereof by regulating the dew point of the carburizing gas in the range +5°C and -3°C, and reheating of the ball portion only being effected in 1 to 2 seconds, followed by immediate quenching of the ball stud.

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