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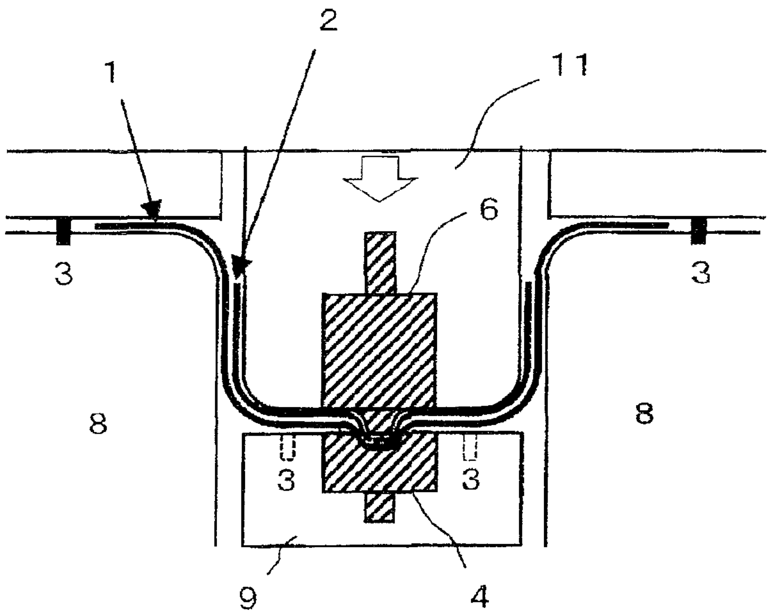
(54) Titre : COMPOSANT D'ASSEMBLAGE PAR RIVETAGE MECANIQUE ET PROCEDE POUR LE FABRIQUER
(54) Title: MECHANICAL CLINCH JOINING COMPONENT AND METHOD FOR MANUFACTURING SAME



(57) Abrégé/Abstract:
In one aspect of the present invention, a mechanical clinched joint component is a mechanical clinched joint component formed of two or more steel sheets, where the component includes at least one joint portion having a peel strength of 0.200 kN/mm or greater, and the component has a hardness of 360 Hv or greater. A method for manufacturing the component sequentially includes heating the two or more steel sheets to an Ac3 temperature or above, and performing mechanical clinch joining so that a carbon equivalent Ceq of the steel sheets, and a bottom-dead-center holding time t and a joining start temperature T during mechanical clinch joining satisfy relationships of equation (1) below and of equation (2) below: $Ceq \times (0.00209 \times t + 0.000731 \times T - 0.0365) \geq 0.200$ ... (1), and $Ceq \geq -0.00071 \times T + 0.993$ ... (2).

Abstract

In one aspect of the present invention, a mechanical clinched joint component is a mechanical clinched joint component formed of two or more steel sheets, where the component includes at least one joint portion having a peel strength of 0.200 kN/mm or greater, and the component has a hardness of 360 Hv or greater. A method for manufacturing the component sequentially includes heating the two or more steel sheets to an Ac3 temperature or above, and performing mechanical clinch joining so that a carbon equivalent Ceq of the steel sheets, and a bottom-dead-center holding time t and a joining start temperature T during mechanical clinch joining satisfy relationships of equation (1) below and of equation (2) below: $Ceq \times (0.00209 \times t + 0.000731 \times T - 0.0365) \geq 0.200$ … (1), and $Ceq \geq -0.00071 \times T + 0.993$ … (2).

Description

Title of Invention

MECHANICAL CLINCH JOINING COMPONENT AND METHOD FOR MANUFACTURING SAME

Technical Field

[0001] The present invention relates to a mechanical clinched joint component and to a method for manufacturing the same, and more particularly, to a high-strength mechanical clinched joint component and to a method for manufacturing such component successfully without occurrence of a defect such as a crack.

Background Art

[0002] An ultra-high-strength steel sheet is increasingly used in a vehicle body frame for providing both collision safety and weight reduction of an automobile. To limit the degree of deformation to a certain level upon an impact of collision, an automobile steel component is reinforced by joining, using spot welding, a reinforcement member to a main member of the steel component to partly increase the thickness of the steel component. However, this method requires a spot welding process for joining after production of both the main member and the reinforcement member, thereby presents a problem of cost increase.

[0003] Meanwhile, as an alternative to spot welding described above, a joining method called mechanical clinch joining is known as a joining method of spot joining by cold working. This joining method is a kind of staking operation to join metal components together mechanically. Table 1 summarizes types of staking operation and features of the respective types. As illustrated in Table 1, there are several types of staking operation. Among these is mechanical clinch joining, which is a method in which two or more metal sheets are pressed at one time using a convex punch and a concave die. This mechanical clinch joining is characterized in that, as illustrated in Table 1, no pretreatment or auxiliary joining elements are required; that the joining process can be performed during press forming; and that application of mechanical clinch joining to a hot forming process further enables the joint portion to be quenched by cooling effect by the die.

[0004] This mechanical clinch joining can reduce cost and increase productivity as compared to spot welding. For example, Patent Literature 1 describes performing of a staking operation called TOX® during pressing, which seems cold pressing. However, this joining method is intended for an outer side panel having a low matrix strength, and is therefore supposedly inapplicable to an ultra-high-strength staked component.

[0005]

[Table 1]

	STAKING OPERATION			
JOINING METHOD	MECHANICAL CLINCHING	SELF-PIERCING RIVET	HOLE + BURRING	LOCK SEAMING
JOINING PERFORMED DURING PARTS FORMING	POSSIBLE	POSSIBLE	POSSIBLE	NOT POSSIBLE
PRETREATMENT	NOT REQUIRED	NOT REQUIRED	HOLE PROCESSING REQUIRED	NOT REQUIRED
AUXILIARY JOINING ELEMENT	NOT REQUIRED	RIVET REQUIRED	NOT REQUIRED	ADHESIVE REQUIRED
QUENCHING BY DIE COOLING IN HOT FORMING	POSSIBLE	NOT POSSIBLE	POSSIBLE	POSSIBLE
JOIN AT PART EDGES	NOT POSSIBLE	NOT POSSIBLE	NOT POSSIBLE	POSSIBLE
JOIN TO PART SURFACE	POSSIBLE	POSSIBLE	POSSIBLE	NOT POSSIBLE

[0006] Mechanical clinch joining by cold working as described above presents a problem in that use of a steel sheet having high strength may cause a crack during joining, and may thus prevent production of a high-strength steel component. On the other hand, Patent Literature 2 describes performing of press work using a press die at a lower temperature under a condition in which a burring portion of the bracket portion member unheated has been fit into a receiving hole of a beam body member at a high temperature at 850°C or above, thus to perform, at one time, forming and quenching of the beam body, and staking of the bracket portion with the beam body by bending or collapsing of the burring portion.

[0007] However, this method requires a bracket portion preparation step to previously form the bracket portion member having a cylindrical flange-shaped burring portion fittable into the receiving hole of the beam body member. That is, production of a complex shape requires another step in addition to the pressing step, thereby increasing the cost. In addition, since use of an ultra-high-strength steel sheet is not taken into account, the heating and staking operation may cause a crack, or cause failure in providing sufficiently high peel strength.

[0008] Therefore, there is a need to manufacture a component having ultra-high strength and sufficiently high peel strength, in particular, a component produced using an ultra-high-strength steel sheet having a tensile strength of 1180 megapascal (MPa) or greater using mechanical clinch joining successfully without occurrence of a defect such as a crack without adding an extra step other than the mechanical clinch joining step.

[0009] The present invention has been made in view of the foregoing background, and it is an object of the present invention is to provide a method for manufacturing a mechanical clinched joint component having ultra-high strength and sufficiently high peel strength using mechanical clinch joining successfully without occurrence of a defect such as a crack without adding an extra step other than the mechanical clinch joining step.

Citation List

Patent Literature

[0010] Patent Literature 1: WO 2013/008515 A

Patent Literature 2: JP 2006-321405 A

Summary of Invention

[0011] In one aspect of the present invention, a mechanical clinched joint component is a mechanical clinched joint component formed of two or more steel sheets, where the component includes at least one joint portion having a peel strength of 0.200 kN/mm or greater, and the component has a hardness of 360 Hv or greater.

[0012] In another aspect of the present invention, a method for manufacturing the mechanical clinched joint component sequentially includes heating the two or more steel sheets to an Ac3 temperature or above; and performing mechanical clinch joining so that a carbon equivalent Ceq of the steel sheets, and a bottom-dead-center holding time t and a joining start temperature T during mechanical clinch joining satisfy relationships of equation (1) below and of equation (2) below:

$$Ceq \times (0.00209 \times t + 0.000731 \times T - 0.0365) \geq 0.200 \qquad \ldots (1)$$

$$Ceq \geq -0.00071 \times T + 0.993 \qquad \ldots (2)$$

where Ceq represents the carbon equivalent (mass%) of the steel sheets calculated by equation (3) below, t represents the bottom-dead-center holding time (second), and T represents the joining start temperature (°C). If a value of Ceq differs in the two or more steel sheets, a lowest value of Ceq is used.

$$Ceq = C + (1/6) \times Mn + (1/24) \times Si + (1/40) \times Ni + (1/5) \times Cr + (1/4) \times Mo + (1/14) \times V \qquad \ldots (3)$$

where each of element names represents a content in mass% in the steel sheets, and represents zero if that element is not contained.

Brief Description of Drawings

[0013] FIG. 1 is a schematic diagram illustrating one aspect of the present invention.

FIGs. 2A to 2C are schematic diagrams illustrating another aspect of the present invention.

FIG. 3 is a diagram illustrating a die having a mechanical clinching tool attached thereto, used in production of test specimens in examples.

FIGs. 4A and 4B are diagrams for describing calculation of the ratio d/D.

FIGs. 5A to 5C are observation images of a cross section of the No. 5 component in one of examples. FIG. 5A is an image of the entire cross section of the component. FIG. 5B is an image of a portion of the cross section of the component. FIG. 5C is an enlarged image of the ellipse portion of FIG. 5B.

FIG. 6 is a chart illustrating the relationship between the left-side value of equation (1) and the CTS/L value.

Description of Embodiments

[0014] The present inventors have carried out considerable research to solve the problem described above. First, to newly investigate the tensile strength limit that causes a crack during joining by cold working, cold forming was performed on steel sheets having a tensile strength from 270 to 1470 MPa and sheet thickness of 1.4 mm to join the steel sheets together crosswise using a die having attached thereto a mechanical clinching tool used in examples described later. The results confirm that, as illustrated in Table 2, a steel sheet tensile strength of 780 MPa or greater has caused a crack during joining, thereby causing failure in mechanical clinch joining. As user herein, the term "mechanical clinch joining" may also be referred to as "joining," and the term "mechanical clinch joining" may also be referred to as "joint component."

[0015]

[Table 2]

STEEL SHEET TENSILE STRENGTH (MPa)	JOINING
270	OK
440	OK
590	OK
780	CRACKED
980	CRACKED
1180	CRACKED
1470	CRACKED

[0016] As described above, the present inventors have carried out considerable research for a method of performing mechanical clinch joining successfully on the assumption that a steel sheet having a tensile strength of 1180 MPa or greater, i.e., an ultra-high-strength steel sheet that is certain to initiate a crack during joining by cold working in view of the results of Table 2 shown above, is used as an ultra-high-strength steel sheet in high demand in recent years. In more detail, considerable researches were carried out to satisfy all the following conditions (A) to (D).

(A) The component exhibits ultra-high strength. Specifically, the component exhibits, as its hardness, a Vickers hardness of 360 Hv or greater, i.e., a tensile strength of 1180 MPa or greater; preferably, a Vickers hardness of 450 Hv or greater, i.e., a tensile strength of 1470 MPa or greater.

(B) The component has high peel strength. Specifically, the component has a cross tensile strength per unit peripheral length of the joint portion determined using a method described later herein, i.e., peel strength, of 0.200 kN/mm or greater.

(C) The component can be manufactured by joining without occurrence of a crack.

(D) No preliminary process before the press work or post-process after the press work is required, and thus a component can be manufactured at a reduced cost.

[0017] In the present invention, the present inventors have found that the relationships between the carbon equivalent Ceq of the steel sheets, and the bottom-dead-center holding time t and the joining start temperature T during mechanical clinch joining need to satisfy equation (1) and equation (2) given later in the joining step after the heating step of heating the steel sheet to a certain temperature or higher.

[0018] That is, a mechanical clinched joint component of the present invention is a mechanical clinched joint component formed of two or more steel sheets, where the component includes at least one joint portion having a peel strength of 0.200 kN/mm or greater, and the component has a hardness of 360 Hv or greater.

[0019] The configuration described above can provide a mechanical clinched joint component having ultra-high strength and sufficiently high peel strength.

[0020] In addition, a method for manufacturing the mechanical clinched joint component of the present invention is characterized in sequentially including heating the two or more steel sheets to an Ac3 temperature or above; and performing mechanical clinch joining so that a carbon equivalent Ceq of the steel sheets, and a bottom-dead-center holding time t and a joining start temperature T during mechanical clinch joining satisfy relationships of equation (1) and of equation (2) given later.

[0021] Such configuration can provide a method for manufacturing the mechanical clinched joint component as described above using mechanical clinch joining successfully without occurrence of a defect such as a crack without adding an extra step other than the mechanical clinch joining step.

[0022] Each step of this embodiment will be described below in detail.

[0023] [Heating Step]

In this embodiment, to perform the joining process described above, the two or more steel sheets are heated to an Ac3 temperature or above first. This heating process facilitates the joining process described later, and enables a joint component having a desired characteristic to be produced. The heating temperature is preferably [Ac3 temperature + 10]°C or higher. An excessively high temperature for this heating temperature results in a coarse microstructure, and thus may reduce ductility or bendability. Thus, the upper limit of the heating temperature is preferably [Ac3 temperature + 180]°C, and more preferably about [Ac3 temperature + 150]°C.

[0024] The Ac3 temperature can be determined using the following equation described in "Leslie Tekkou Zairyougaku" (originally titled "The Physical Metallurgy of Steels," Maruzen Co., Ltd., published on May 31, 1985, p.273). In the following equation, the expression [element name] represents the content in mass% of that element contained in the steel. In the following equation, the value for an element not contained can be calculated as zero.

$$\text{Ac3 transformation point } (^\circ\text{C}) = 910 - 203 \times [\text{C}]0.5 - 15.2 \times [\text{Ni}] + 44.7 \times [\text{Si}] + 104 \times [\text{V}] + 31.5 \times [\text{Mo}] + 13.1 \times [\text{W}] - 30 \times [\text{Mn}] - 11 \times [\text{Cr}] - 20 \times [\text{Cu}] + 700 \times [\text{P}] + 400 \times [\text{Al}] + 400 [\text{Ti}]$$

[0025] The heating duration at the heating temperature described above is preferably one minute or more. In addition, in view of limiting grain growth of austenite and the like, the heating duration is preferably 15 minutes or less. The temperature may be raised to the Ac3 transformation point at any rate. Examples of the method of heating include furnace heating, Joule heating, and induction heating.

[0026] [Joining Step]

The present inventors have considered conditions for this joining step particularly to increase the peel strength of the joint portion of the joint component. First, in this embodiment, due to the dependence of the cross tensile strength CTS on the length L of the joint portion, the value CTS/L obtained by division of CTS by L is used as the peel strength. This allows peel strength to be evaluated regardless of the size of the joint portion. In examples described later which use circular joint portions, the value L corresponds to the circumference of this circular shape.

[0027] In this embodiment, joining conditions have also been considered to provide a component having a component hardness and the above peel strength of a certain predetermined value or greater, in particular, the peel strength CTS/L of 0.200 kN/mm or greater. Specifically, manufacturing of a mechanical clinched joint component using different steel sheet compositions, different bottom-dead-center holding times, and different joining start temperatures as shown in examples described later has shown that joining conditions exist for forming a component having the component hardness and the peel strength each of a certain predetermined value or greater without occurrence of a crack.

[0028] Further consideration has been made to find these joining conditions. First, considering that the peel strength seems to be affected after stamping, that is, by the hardness of the matrix of the component, that the hardness of the matrix is affected by the steel sheet quenching property, the quenching start temperature, and the bottom-dead-center holding time t, and that the quenching start temperature corresponds to the joining start temperature T in this embodiment, the peel strength CTS/L is expressed as equation (4) given below using the carbon equivalent Ceq, serving as an index of the steel sheet quenching property, the bottom-dead-center holding time t, and the joining start temperature T. In equation (4) below, the value Ceq (mass%) is a value calculated from equation (3) below defined in JIS G 0203, and the values a, b, and c are coefficients.

$$CTS/L = Ceq \times (a \times t + b \times T + c) \quad \dots (4)$$

$$Ceq = C + (1/6) \times Mn + (1/24) \times Si + (1/40) \times Ni + (1/5) \times Cr + (1/4) \times Mo + (1/14) \times V \quad \dots (3)$$

where each of the element names represents the content in mass% in the steel sheets, and represents zero if that element is not contained.

[0029] The present inventors have manufactured mechanical clinched joint components using different steel sheet compositions, different bottom-dead-center holding times, and different joining start temperatures as described in examples described later, and performed experiments of determining peel strength of the components manufactured. To find out an equation for achieving a peel strength of 0.200 kN/mm or greater, multiple regression analysis has been performed on the experimental results to determine the values of the coefficients a, b, and c in equation (4) above, and equation (1) below has thus been obtained.

$$Ceq \times (0.00209 \times t + 0.000731 \times T - 0.0365) \geq 0.200 \quad \dots (1)$$

where Ceq represents the carbon equivalent (mass%) of the steel sheets calculated by equation (3) below, t represents the bottom-dead-center holding time (second), and T represents the joining start temperature (°C). If the value of Ceq differs in the two or more steel sheets, the lowest value of Ceq is used.

$$Ceq = C + (1/6) \times Mn + (1/24) \times Si + (1/40) \times Ni + (1/5) \times Cr + (1/4) \times Mo + (1/14) \times V \quad \dots (3)$$

[0030] It is likely that satisfaction of equation (1) above reduces a ratio d/D of the joint diameter d of the product with respect to the die diameter D, thereby enabling the peel strength to be improved.

[0031] In this embodiment, satisfaction of equation (2) below is further required. Equation (2) below is given in view of the fact that the joining start temperature is affected by the steel sheet constituent composition, in particular, by Ceq among others. Equation (2) below has also been drawn by manufacturing mechanical clinched joint components using different steel sheet compositions and different joining start temperatures, and by performing experiments of determining peel strength of the components manufactured.

$$\mathrm{Ceq} \geq -0.00071 \times T + 0.993 \qquad \ldots (2)$$

where Ceq represents the carbon equivalent (mass%) of the steel sheets calculated by equation (3) above, and T represents the joining start temperature (°C).

[0032] The two or more steel sheets used in mechanical clinch joining of this embodiment may have different constituent compositions, i.e., different Ceq values, between the steel sheets. In such case, the lowest value of Ceq is used in equation (1) and in equation (2).

[0033] Performing joining under the conditions that satisfy equation (1) and equation (2) above enables all the conditions (A) to (D) to be satisfied. That is, a mechanical clinched joint component having (A) component strength of $\mathrm{Hv} \geq 360$ and (B) peel strength of $\mathrm{CTS/L} \geq 0.200$ kN/mm can be manufactured without adding a preliminary process or post-process and at a reduced cost. Forming the shape of a component by mechanical clinch joining serves similarly to forming the shape of a component by pressing, and may thus contribute to improvement in rigidity of the component.

[0034] In this embodiment, it suffices that the method for manufacturing a joint component satisfy the conditions described above, and other conditions are not particularly limited. In view of limiting an increase in forming load and reduction in formability, the joining start temperature is preferably 400°C or higher. The bottom-dead-center holding time preferably has a longer value in view of improvement in peel strength, but if productivity is of importance, or a multiple-step process described later is performed, the bottom-dead-center holding time for one joining operation is preferably 3 seconds or less.

[0035] In this embodiment, hot press forming may also be performed in the step of performing mechanical clinch joining. The hot press forming may be performed under any conditions, and may be performed using a commonly used method. To perform hot press forming successfully, the temperature at the start of press forming, i.e., at the time when the die reaches the position in contact with the steel sheet, is preferably about 400°C or higher.

[0036] The method for manufacturing a joint component of this embodiment needs only to include the heating step and the joining step described above in this order. The joining step may be performed only once, or twice or more. In addition, during a time period from heating to completion of forming of the steel sheets, a step, for example, of processing the steel sheets as described in the first step of the second aspect described below may be performed as other step than the joining step. This embodiment eliminates the need to perform other step than the heating and forming steps, thereby enabling a joint component to be manufactured at high productivity at a reduced cost.

[0037] Specific aspects of the manufacturing method according to this embodiment in a case in which joining is performed simultaneously with hot press forming include, for example, a first aspect and a second aspect described below. However, the present invention is not limited to these aspects. Although examples described below are described in terms of spot joining for a circular clinched portion, other aspects including other shapes, such as spot joining of rectangular portion and linear joining along the longitudinal direction of the component, are also within the scope of the present invention.

[0038] Description is herein given with reference to the drawings, in which the reference symbols have meanings as follows: 1 steel sheet, 2 another steel sheet or reinforcement member steel sheet, 3 support platform, 4 joining die, 5 joining die holder, 6 joining punch, 7 joining punch holder, 8 pressing die, 9 pad, 10 excess length producing punch, 11 pressing punch, 12A, 12B, 12C joint portion, 13 component vertical wall portion, 14A upper sheet, 14B lower sheet, and 14C interface between upper and lower sheets.

[0039] [First aspect: single-step process]

In a first aspect, the forming process can be performed, for example, using a device illustrated in FIG. 1. In more detail, a steel sheet 1 heated and another steel sheet 2 heated serving as a reinforcement member are stacked together one on top of another, are placed on a support platform 3, and are air-cooled to a joining start temperature. A pressing punch 11 including therein a joining punch 6 is lowered to perform press forming and joining at one time. FIG. 1 illustrates a situation in which the bottom dead center has been reached. In this first aspect, as illustrated in FIG. 1, the steel sheets 1 and 2 are press-formed by the pressing die 8, the pad 9, and the pressing punch 11, and at the same time, are joined together by a joining die 4 included in the pad 9 and by the joining punch 6.

[0040] [Second aspect: multiple-step process]

In a second aspect, the forming process can be performed, for example, as illustrated in FIGs. 2A to 2C. As illustrated in FIGs. 2A to 2C, the steel sheets are heated, and thereafter, a first step illustrated in FIG. 2A, a second step illustrated in FIG. 2B, and a third step illustrated in FIG. 2C are performed consecutively. Each of these steps will now be described. First, at the first step, the steel sheet 1 heated is placed on the support platform 3, and an excess length producing punch 10 is then lowered to produce an excess length in the steel sheet 1 that will form the outer wall of the component as illustrated in FIG. 2A. Next, at the second step, the other steel sheet 2 is placed over the steel sheet 1 having the excess length, and the joining punch 6 is then lowered to join together the steel sheets 1 and 2 at two points by the joining punch 6 and by the joining die 4 included in the pressing die 8 as illustrated in FIG. 2B. Thus, joint portions 12A and 12B are produced.

[0041] Then, at a third step, which is the last step, hot press forming and joining are performed at one time. In more detail, the pressing punch 11 including therein the joining punch 6 is lowered to perform press forming as well as joining. FIG. 2C illustrates a situation in which the bottom dead center has been reached. In this third step, as illustrated in FIG. 2C, the steel sheets 1 and 2 are press-formed by the pressing die 8, the pad 9, and the pressing punch 11, and at the same time, are joined together by the joining die 4 included in the pad 9 and by the joining punch 6 to form a joint portion 12C. This step enables the joint portions 12A and 12B to be formed on a component vertical wall portion 13.

[0042] In a case of an automobile steel component, the steel sheet 1 and the other steel sheet 2 are applicable, for example, respectively as an outer component and an inner component. Although the foregoing aspects does not mention, the joining step may be performed on a same portion twice or more as described in Example 2 described below.

[0043] The constituents of the steel sheets for use in the joining described above are not particular limited. For example, the two or more steel sheets may satisfy the conditions of constituent composition given below. Examples of usable type of steel sheet include hot-rolled steel sheets, cold-rolled steel sheets, plated steel sheets such as galvanized steel sheets produced by plating these steel sheets, and alloyed hot-dip galvanized steel sheets produced by further performing alloying. This method is applicable not only to joining of steel sheets, but also to joining of different materials (i.e., application of multi-material technology) such as a steel sheet and an aluminum sheet.

[0044] The constituent compositions of the steel sheets forming the component of this embodiment, that is, the constituent compositions of the steel sheets for use in the joining may include the composition described below. Note that, as used in the description of constituent composition given below, the unit "%" means mass% unless otherwise indicated.

[0045] [C: 0.15 to 0.4%]

To readily achieve a component hardness of 360 Hv or greater, the content of C is preferably 0.15% or more. The content of C is more preferably 0.17% or more, and is still more preferably 0.20% or more. Meanwhile, in view of weldability of the member produced, the content of C is preferably up to 0.4% or less, more preferably 0.30% or less, and still more preferably 0.26% or less.

[0046] [Si: more than 0% to 2% or less]

Silicon (Si) is an element effective in improving the quenching property of a hot-pressed steel sheet, and in stably ensuring the strength of a hot press-formed component. From this viewpoint, the content of Si is preferably 0.05% or more, and more preferably 0.15% or more. However, an excess content of Si impedes production of a milder steel sheet for hot pressing, and moreover, significantly raises the Ac3 temperature, thereby causing the ferrite component to remain at the heating stage in hot pressing. This makes it hard to achieve high strength. Thus, the content of Si is preferably 2% or less, more preferably 1.65% or less, and still more preferably 1.45% or less.

[0047] [At least one of Mn and Cr: 1.0 to 5.0% in total]

Manganese (Mn) and chromium (Cr) are each an element useful for improving the quenching property of a steel sheet to produce a high-strength member. These elements may be used alone or in combination of two or more. From the viewpoint described above, at least one of

Mn and Cr is contained preferably with a content of 1.0% or more in total, more preferably 1.5% or more in total, still more preferably 1.8% or more in total, and yet further preferably 2.0% or more in total. However, an excess content of any of these elements only results in saturation of the effect thereof, and thus results in a cost increase. Thus, in this embodiment, at least one of Mn and Cr is contained preferably with a content of 5.0% or less in total, more preferably 3.5% or less in total, and still more preferably 2.8% or less in total.

[0048] The constituent composition may include the constituents described above, with the balance being iron and incidental impurities. The incidental impurities may include, for example, phosphorus (P), sulfur (S), and nitrogen (N) as described below.

[0049] Since phosphorus reduces ductility, the content of P is preferably limited to 0.05% or less, more preferably to 0.045% or less, and still more preferably to 0.040% or less. Note that the content of P cannot be reduced to 0% for manufacturing reasons, and thus, the lower limit of the content of P is greater than 0%.

[0050] Sulfur also reduces ductility similarly to P, the content of S is preferably limited to 0.05% or less, more preferably to 0.045% or less, and still more preferably to 0.040% or less. Note that the content of S cannot be reduced to 0% for manufacturing reasons, and thus, the lower limit of the content of S is greater than 0%.

[0051] Nitrogen fixes boron (B) as BN, thereby reducing the quenching property improvement effect. In addition, nitrogen forms coarse Ti-containing segregation such as TiN segregation, which may act as a starting point of fracture, and reduce the ductility of the steel sheets. Thus, the content of N is preferably 0.01% or less, more preferably 0.008% or less, and still more preferably 0.006% or less. Note that the content of N cannot be reduced to 0% for manufacturing reasons, and thus, the lower limit of the content of N is greater than 0%.

[0052] In addition to the elements described above, containing of selective element(s) described below such as titanium (Ti) in a suitable amount can have effects such as facilitation of achievement of high strength. If at least one of Ti, B, aluminum (Al), molybdenum (Mo), copper (Cu), nickel (Ni), niobium (Nb), vanadium (V), and zirconium (Zr) is contained, these elements may be used alone or in combination of two or more. These elements will be described below.

[0053] [Ti: 0% or more to 0.10% or less]

Titanium fixes nitrogen as TiN to cause boron to exist in a solid solution state, and is thus effective in providing good quenching property. If such effect of titanium is to be utilized, the content of Ti is preferably greater than 0%, more preferably 0.015% or more, and still more preferably 0.020% or more. Meanwhile, an excess content of Ti increases the strength of the steel sheets to be processed more than necessary, thereby decreasing the lives of cutting tool and punching die, and thus increasing the cost. Therefore, the content of Ti is preferably 0.10% or less, more preferably 0.06% or less, and still more preferably 0.04% or less.

[0054] [B: 0% or more to 0.005%or less]

Boron is an element useful for improving the quenching property of a steel product to achieve high strength even using slow cooling. If such effect of boron is to be utilized, the content of B is preferably greater than 0%, more preferably 0.0003% or more, still more preferably 0.0015% or more, and yet further preferably 0.0020% or more. Meanwhile, an excess content of B results in excess generation of BN, thereby decreasing in toughness. Thus, the content of B is preferably 0.005% or less, more preferably 0.0040% or less, and still more preferably 0.0035% or less.

[0055] [Al: 0% or more to 0.5% or less]

Aluminum is an element used for deacidification. If this effect is to be utilized, the content of Al is preferably greater than 0%, and more preferably 0.01% or more. Meanwhile, a higher content of Al has a larger effect on raising the Ac3 temperature, thereby requiring a higher heating temperature in hot pressing, which reduces production efficiency. Thus, the content of Al is preferably 0.5% or less, more preferably 0.20% or less, still more preferably 0.10% or less, and yet further preferably 0.050% or less.

[0056] [Mo: 0% or more to 1% or less]

Molybdenum is an element effective in improving the quenching property of a steel sheet. It is expected that containing of this element reduce variation in hardness of the formed products. If this effect of molybdenum is to be utilized, the content of Mo is preferably greater than 0%, more preferably 0.01% or more, and still more preferably 0.1% or more. However, an excess content of Mo only results in saturation of this effect, and thus results in a cost increase. Thus, the content of Mo is preferably 1% or less, more preferably 0.8% or less, and still more preferably 0.5% or less.

[0057] [Cu: 0% or more to 0.5% or less]

Copper is an element effective in improving the quenching property, and is also useful for improving delayed-fracture resistance and oxidation resistance of a formed product. If this effect of copper is to be utilized, the content of Cu is preferably greater than 0%, more preferably 0.01% or more, and still more preferably 0.1% or more. However, an excess content of Cu may cause a surface flaw during steel sheet manufacturing. This will degrade pickling property, and thus reduce productivity. Thus, the content of Cu is preferably 0.5% or less, and more preferably 0.3% or less.

[0058] [Ni: 0% or more to 0.5% or less]

Nickel is an element effective in improving the quenching property, and is also useful for improving delayed-fracture resistance and oxidation resistance of a formed product. If this effect of nickel is to be utilized, the content of Ni is preferably greater than 0%, more preferably 0.01% or more, and still more preferably 0.1% or more. However, an excess content of Ni may cause a surface flaw during steel sheet manufacturing. This will degrade pickling property, and thus reduce productivity. Thus, the content of Ni is preferably 0.5% or less, and more preferably 0.3% or less.

[0059] [Nb: 0% or more to 0.10% or less]

Niobium is an element having an effect of constructing a finer structure, thereby contributing to an increase in toughness. Thus, if niobium is to be contained, the content of Nb is preferably greater than 0%, more preferably 0.005% or more, and still more preferably 0.010% or more. Meanwhile, an excess content of Nb increases the strength of the steel sheets, thereby reducing the tool life in the blanking step including an operation such as cutting a steel sheet into a predetermined shape before hot press forming. This increases the cost. Thus, the content of Nb is preferably 0.10% or less, and more preferably 0.05% or less.

[0060] [V: 0% or more to 0.10% or less]

Vanadium is an element having an effect of constructing a finer structure, thereby contributing to an increase in toughness. Thus, if vanadium is to be contained, the content of V is preferably greater than 0%, more preferably 0.005% or more, and still more preferably 0.010% or more. Meanwhile, an excess content of V increases the strength of the steel sheets similarly to the case of Nb, thereby reducing the tool life in the blanking step. This increases the cost. Thus, the content of V is preferably 0.10% or less, and more preferably 0.05% or less.

[0061] [Zr: 0% or more to 0.10% or less]

Zirconium is an element having an effect of constructing a finer structure, thereby contributing to an increase in toughness. Thus, if zirconium is to be contained, the content of Zr is preferably greater than 0%, more preferably 0.005% or more, and still more preferably 0.010% or more. Meanwhile, an excess content of Zr increases the strength of the steel sheets similarly to the cases of Nb and V, thereby reducing the tool life in the blanking step. This increases the cost. Thus, the content of Zr is preferably 0.10% or less, and more preferably 0.05% or less.

[0062] The method for manufacturing the steel sheets are not limited either. It is sufficient to perform, using general methods, casting, heating, and hot rolling, and pickling followed by cold rolling as needed, and furthermore, annealing as needed. In addition, the hot-rolled steel sheet or cold-rolled steel sheet produced may be plated, as needed, using plating such as zinc-containing plating using a general method, and then further be alloyed as needed.

[0063] Various aspects of technology are disclosed herein as described above, some of which will be summarized below.

[0064] In one aspect of the present invention, a mechanical clinched joint component is a mechanical clinched joint component formed of two or more steel sheets, where the component includes at least one joint portion having a peel strength of 0.200 kN/mm or greater, and the component has a hardness of 360 Hv or greater.

[0065] In another aspect of the present invention, a method for manufacturing the mechanical clinched joint component sequentially includes heating the two or more steel sheets to an Ac3 temperature or above; and performing mechanical clinch joining so that a carbon equivalent Ceq of the steel sheets, and a bottom-dead-center holding time t and a joining start temperature T during mechanical clinch joining satisfy relationships of equation (1) below and of equation (2) below:

$$Ceq \times (0.00209 \times t + 0.000731 \times T - 0.0365) \geq 0.200 \quad \ldots (1)$$

$$Ceq \geq -0.00071 \times T + 0.993 \quad \ldots (2)$$

where Ceq represents the carbon equivalent (mass%) of the steel sheets calculated by equation (3) below, t represents the bottom-dead-center holding time (second), and T represents the joining start temperature (°C). If the value of Ceq differs in the two or more steel sheets, a lowest value of Ceq is used.

$$Ceq = C + (1/6) \times Mn + (1/24) \times Si + (1/40) \times Ni + (1/5) \times Cr + (1/4) \times Mo + (1/14) \times V \quad \ldots (3)$$

where each of element names represents a content in mass% in the steel sheets, and represents zero if that element is not contained.

[0066] The two or more steel sheets used in the method for manufacturing the mechanical clinched joint component may each have a constituent composition in mass% satisfying:

C: 0.15 to 0.4%,

Si: more than 0% to 2% or less, and

at least one of Mn and Cr: 1.0 to 5.0% in total, and

further satisfying Ti: 0% or more to 0.10% or less, B: 0% or more to 0.005% or less, Al: 0% or more to 0.5% or less, Mo: 0% or more to 1% or less, Cu: 0% or more to 0.5% or less, Ni: 0% or more to 0.5% or less, Nb: 0% or more to 0.10% or less, V: 0% or more to 0.10% or less, and Zr: 0% or more to 0.10% or less.

[0067] The method for manufacturing the mechanical clinched joint component may also perform hot press forming in the step of performing mechanical clinch joining.

[0068] The method for manufacturing the mechanical clinched joint component may perform the step of performing mechanical clinch joining a plurality of times.

Examples

[0069] The present invention will be described below more specifically using examples. However, the present invention is not limited to examples described below, and various modifications commensurate with the spirit described above and below may be made thereto. The technical scope of the present invention encompasses all such modifications.

[0070] [Example 1]

A steel sheet A and a steel sheet B having constituent compositions illustrated in Table 3 were each used to prepare two specimens having a dimension of 150 mm × 50 mm × sheet thickness 1.4 mm, and each pair of the two test specimens was mechanically clinched together using the tool illustrated in FIG. 3. In more detail, referring to FIG. 3, the steel sheet 1 and the other steel sheet 2 heated at 930°C for 4 minutes were stacked together, crosswise, one on top of another, and were placed on the support platform 3 between the joining punch 6 included in the joining punch holder 7 and the joining die 4 included in the joining die holder 5. After air cooling to the joining start temperature described below, the joining die 4 was lowered to perform mechanical clinch joining under the conditions listed below, and test specimens representing the component were thus produced.

[0071] (Joining condition)

Holder pressure: 3 ton-force (tonf)

Punch diameter: Dp = 10.0 mm

Die diameter: D = 14.0 mm

Forming rate: 20 spm

Joining start temperature: as illustrated in Table 4 for the steel sheet A, and as illustrated in Table 5 for the steel sheet B

Bottom-dead-center holding time: as illustrated in Table 4 for the steel sheet A, and as illustrated in Table 5 for the steel sheet B

[0072] The hardness and peel strength of the test specimens produced were determined as follows.

[0073] (Determination of hardness of test specimen)

As the hardness of a test specimen, Vickers hardness Hv was determined at three points per steel sheet under a load condition of 1 kgf in a portion other than the joint portion, i.e., in a holder portion of the component, at a location of 1/4 sheet thickness of each steel sheet that constitute the component. The results of the three points were averaged for each steel sheet, and the lowest average value in the steel sheets was used as the hardness of that component. Evaluation was made against the following criteria.

[0074] (Hardness evaluation criteria)

Very Good: $Hv \geq 450$

Good: $450 > Hv \geq 360$

Poor: $360 > Hv$

[0075] (Determination of peel strength of test specimen)

The cross tensile strength CTS (kN) of each test specimen was measured according to JIS Z 3137. This CTS value was divided by the circumference L (mm) of the joint portion to calculate the cross tensile strength per unit peripheral length CTS/L (kN/mm) of the joint portion as the peel strength. A peel strength corresponding to this CTS/L value of 0.200 kN/mm or greater was classified as high.

[0076] FIGs. 4A and 4B are diagrams illustrating cross sections of the die used and of the joint component produced. As illustrated in FIG. 4B, the joint diameter d of the joint component was measured, and then a value of d/D was also calculated by dividing this joint diameter d by the die diameter D illustrated in FIG. 4A. A smaller d/D value indicates stronger joining, and the value of d/D is preferably 1.029 or less.

[0077] The results for the steel sheet A and the results for the steel sheet B are respectively included in Table 4 and in Table 5.

[0078]

[Table 3]

STEEL SHEET	CONSTITUENT COMPOSITION (MASS%) WITH BALANCE OF IRON AND INCIDENTAL IMPURITIES OTHER THAN P, S, AND N										Ceq (MASS%)	Ac_3 (°C)
	C	Si	Mn	P	S	Cr	Ti	B	Al	N		
A	0.231	0.18	1.29	0.012	0.0030	0.21	0.024	0.0029	0.039	0.0049	0.496	910
B	0.219	1.13	2.21	0.011	0.0010	0.02	0.023	0.0019	0.045	0.0036	0.638	928

[0079]

[Table 4]

No.	STEEL SHEET	Ceq (MASS%)	JOINING START TEMPERATURE T (°C)	BOTTOM-DEAD-CENTER HOLDING TIME t (SECOND)	Ceq×f(T,t)※	-0.00071×T+0.993	HARDNESS Hv	PEEL STRENGTH CTS/L (kN/mm)	d/D
1	A	0.496	800	2.5	0.2742	0.4250	GOOD	0.280	1.023
2			800	5	0.2768	0.4250	GOOD	0.302	1.017
3			800	7.5	0.2794	0.4250	GOOD	0.307	1.015
4			800	10	0.2820	0.4250	VERY GOOD	0.307	1.024
5			700	2.5	0.2380	0.4960	GOOD	0.254	1.029
6			700	5	0.2406	0.4960	GOOD	0.263	1.028
7			700	7.5	0.2432	0.4960	GOOD	0.248	1.027
8			700	10	0.2458	0.4960	VERY GOOD	0.269	1.024
9			600	10	0.2096	0.5670	POOR	0.104	1.030

※ Ceq×f(T,t)=Ceq×(0.00209×t+0.000731×T−0.0365)

[0080]

[Table 5]

No.	STEEL SHEET	Ceq (MASS%)	JOINING START TEMPERATURE T (°C)	BOTTOM-DEAD-CENTER HOLDING TIME t (SECOND)	Ceq×f(T,t)※	-0.00071×T+0.993	HARDNESS Hv	PEEL STRENGTH CTS/L (kN/mm)	d/D
1	B	0.638	800	0	0.3500	0.4250	VERY GOOD	0.316	1.0270
2			800	2.5	0.3533	0.4250	VERY GOOD	0.337	1.0130
3			800	5	0.3567	0.4250	VERY GOOD	0.349	1.0111
4			800	7.5	0.3600	0.4250	VERY GOOD	0.369	1.0093
5			800	10	0.3633	0.4250	VERY GOOD	0.381	0.9963
6			700	0	0.3033	0.4960	VERY GOOD	0.319	1.0125
7			700	2.5	0.3067	0.4960	VERY GOOD	0.343	1.0195
8			700	10	0.3167	0.4960	VERY GOOD	0.342	1.0111
9			600	0	0.2567	0.5670	VERY GOOD	0.248	1.0158
10			600	10	0.2700	0.5670	VERY GOOD	0.313	1.0181
11			500	0	0.2100	0.6380	VERY GOOD	0.212	1.0176
12			500	10	0.2233	0.6380	VERY GOOD	0.282	1.0204
13			400	0	0.1633	0.7090	NOT JOINABLE		
14			400	2.5	0.1667	0.7090	VERY GOOD	0.137	1.0310
15			400	5	0.1700	0.7090	VERY GOOD	0.150	1.0300
16			300	0	0.1167	0.7800	CRACK OCCURRED DURING JOINING		

※ Ceq×f(T,t)=Ceq×(0.00209×t+0.000731×T−0.0365)

[0081] First, Table 4 shows the following results for the case of the steel sheet A. Specimens Nos. 1 to 8 are those of examples of performing mechanical clinch joining so that the carbon equivalent Ceq of the steel sheets used, and the bottom-dead-center holding time t and the joining start temperature T during mechanical clinch joining satisfy relationships of predetermined equation (1) and equation (2). In these examples, joining was performed successfully without occurrence of a crack, and the component produced had a high hardness Hv corresponding to 1180 MPa or greater, and a peel strength CTS/L of 0.200 kN/mm or greater. Among these, as shown by the results of

Nos. 4 and 8, a bottom-dead-center holding time of 10 seconds resulted in satisfactory hardness. In particular, as shown by the result of No. 4, a combination of a joining start temperature of 800°C and a bottom-dead-center holding time of 10 seconds further resulted in sufficiently high peel strength.

[0082] On the contrary, specimen No. 9 had a joining start temperature that did not satisfy equation (2), thereby caused a soft phase to segregate. Therefore, even though no cracks occurred, the hardness was low, and the peel strength was also low.

[0083] Next, Table 5 shows the following results for the case of the steel sheet B. Specimens Nos. 1 to 12 are those of examples of performing mechanical clinch joining so that the carbon equivalent Ceq of the steel sheets used, and the bottom-dead-center holding time t and the joining start temperature T during mechanical clinch joining satisfy relationships of predetermined equation (1) and equation (2). In these examples, joining was performed successfully without occurrence of a crack, and the component produced had a high hardness Hv corresponding to 1180 MPa or greater, and a peel strength CTS/L of 0.200 kN/mm or greater. In particular, a joining start temperature of 500°C or higher achieved both $Hv \geq 450$ and $CTS/L \geq 0.200$kN/mm even without holding at the bottom dead center.

[0084] Among these, as shown by the result of No. 5, a combination of a joining start temperature of 800°C and a bottom-dead-center holding time of 10 seconds resulted in sufficiently high peel strength. Observation of a cross section of this specimen No. 5 as illustrated in FIG. 5A shows that planar pressure exerted at the interface between the heated steel sheets during mechanical clinch joining accelerates interdiffusion to cause diffusion joining, as illustrated in FIG. 5B, and in FIG. 5C that illustrates an enlarged image of the ellipse portion of FIG. 5B. It is likely that this diffusion joining has provided higher peel strength in specimen No. 5.

[0085] As illustrated in Table 5, in the case of the steel sheet B, steel sheets can be joined together using a joining start temperature from 500 to 600°C, and in addition, the bottom-dead-center holding time can be reduced or omitted. This enables joining in a multiple-step process, and joining to a vertical wall portion such as one illustrated in FIGs. 2A to 2C is also possible.

[0086] In contrast, a joining start temperature of 400°C caused no cracks to occur, but as shown by the result of No. 13 in particular, omission of holding at the bottom dead center caused failure in staking the portions to be joined. Thus, the steel sheets were not joinable. In addition, as shown by the results of Nos. 14 and 15, the holding times of 2.5 seconds and of 5 seconds could provide the hardness satisfying $Hv \geq 360$, but the peel strengths were unsatisfactory.

[0087] In addition, as shown by the result of No. 16, a joining start temperature of 300°C caused a crack to occur during joining.

[0088] FIG. 6 drawn based on the results of Table 4 and Table 5 above shows that the left-side values of equation (1) and CTS/L values almost match.

[0089] [Example 2]

In this Example, evaluation was made on properties for cases in which specimens of the steel sheet B were joined together at a same portion multiple times. In more detail, the procedures for the respective examples of Table 6 were as follows.

• No. 1: heated to 930°C → air-cooled to a joining start temperature of 800°C → mechanical clinch joining → property evaluation

• No. 2: heated to 930°C → air-cooled to a joining start temperature of 800°C → first mechanical clinch joining → second mechanical clinch joining → property evaluation

• No. 3: heated to 930°C → air-cooled to a joining start temperature of 800°C → first mechanical clinch joining → second mechanical clinch joining → third mechanical clinch joining → property evaluation

[0090] The mechanical clinch joining described above was performed using the tool illustrated in FIG. 3 under the conditions illustrated in Table 6. The properties, i.e., hardness, peel strength, and d/D, of the test specimens produced were determined similarly to Example 1. The results are illustrated in Table 6.

[0091]

[Table 6]

No.	STEEL SHEET	Ceq (MASS%)	JOINING START TEMPERATURE T (°C)	BOTTOM-DEAD-CENTER HOLDING TIME t (SECOND)	NUMBER OF JOINING OPERATIONS	Ceq × f(T,t) ※	−0.00071 × T+0.993	HARDNESS Hv	PEEL STRENGTH CTS/L (kN/mm)	d/D
1	B	0.638	800	0	1	0.3500	0.4250	VERY GOOD	0.316	1.027
2			800	0	2	0.3533	0.4250	VERY GOOD	0.324	1.025
3			800	0	3	0.3567	0.4250	VERY GOOD	0.334	1.021

※ $Ceq \times f(T,t) = Ceq \times (0.00209 \times t + 0.000731 \times T - 0.0365)$

[0092] Table 6 shows that performing a higher number of the joining operations increases the peel strength CTS/L. This may be because, despite the bottom-dead-center holding time being zero, pressing a same portion consecutively increases the number of contacts between the steel sheet and the tool to increase the total contact time therebetween, thereby decreasing the d/D value.

[0093]

[0094] To describe the invention, the invention has been described in the foregoing description appropriately and sufficiently using embodiments with reference to specific examples and the like. However, it is to be understood that changes and/or modifications to the foregoing embodiments will readily occur to those skilled in the art. Therefore, unless a change or modification made by those skilled in the art is beyond the scope of the appended claims, such change or modification is to be embraced within the scope of the appended claims.

Industrial Applicability

[0095] The present invention has a wide range of industrial applicability in technical fields relating to mechanical clinch joining.

Claims

1. A method for manufacturing a mechanical clinched joint component, the method sequentially comprising:

heating two or more steel sheets to an Ac3 temperature or above; and

performing mechanical clinch joining so that a carbon equivalent Ceq of the steel sheets, and a bottom-dead-center holding time t and a joining start temperature T during mechanical clinch joining satisfy relationships of equation (1) below and of equation (2) below:

$$Ceq \times (0.00209 \times t + 0.000731 \times T - 0.0365) \geq 0.200 \quad ... (1)$$

$$Ceq \geq -0.00071 \times T + 0.993 \quad ... (2)$$

where Ceq represents the carbon equivalent (mass%) of the steel sheets calculated by equation (3) below, t represents the bottom-dead-center holding time (second), and T represents the joining start temperature (°C), wherein, if a value of Ceq differs in the two or more steel sheets, a lowest value of Ceq is used,

$$Ceq = C + (1/6) \times Mn + (1/24) \times Si + (1/40) \times Ni + (1/5) \times Cr + (1/4) \times Mo + (1/14) \times V \quad ... (3)$$

where each of element names represents a content in mass% in the steel sheets, and represents zero if that element is not contained.

2. The method for manufacturing the mechanical clinched joint component according to claim 1, wherein the two or more steel sheets each has a constituent composition in mass% satisfying:

C: 0.15 to 0.4%,

Si: more than 0% to 2% or less, and

at least one of Mn and Cr: 1.0 to 5.0% in total, and

further satisfying Ti: 0% or more to 0.10% or less, B: 0% or more to 0.005% or less, Al: 0% or more to 0.5% or less, Mo: 0% or more to 1% or less, Cu: 0% or more to 0.5% or less, Ni: 0% or more to 0.5% or less, Nb: 0% or more to 0.10% or less, V: 0% or more to 0.10% or less, Zr: 0% or more to 0.10% or less.

3. The method for manufacturing the mechanical clinched joint component according to claim 1, wherein hot press forming is also performed in the step of performing mechanical clinch joining.

4. The method for manufacturing the mechanical clinched joint component according to claim 1, wherein the step of performing mechanical clinch joining is performed a plurality of times.

FIG. 1

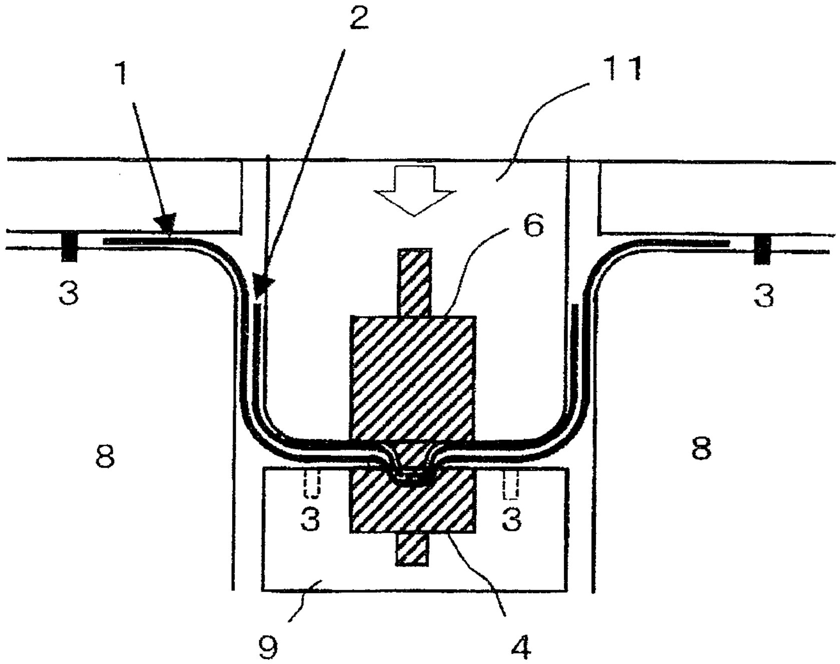


FIG. 2A

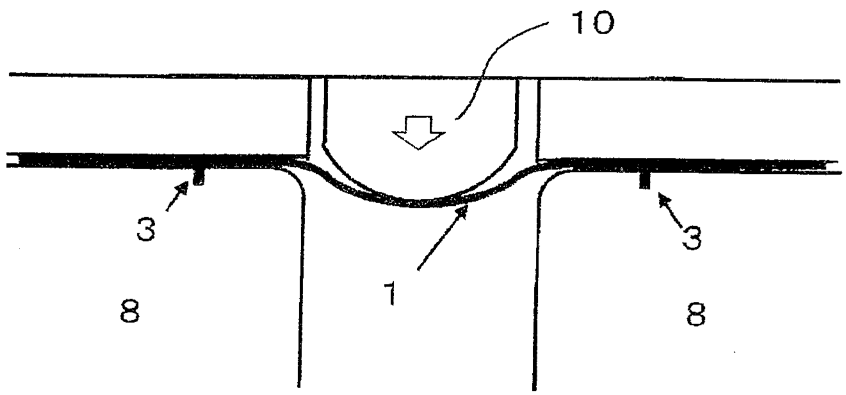


FIG. 2B

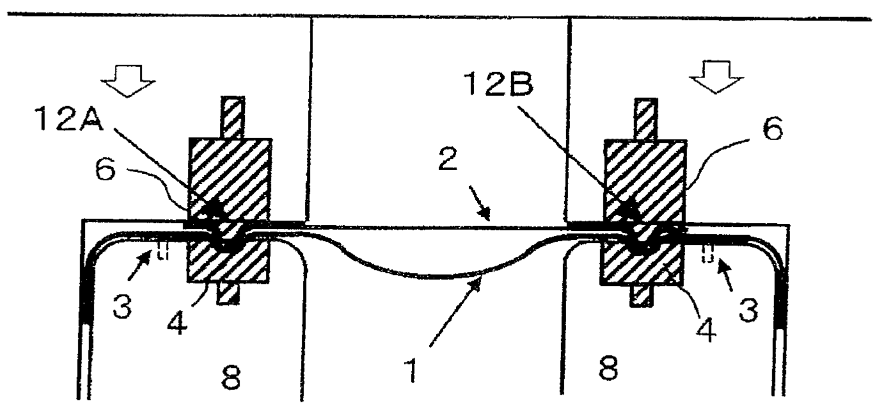


FIG. 2C

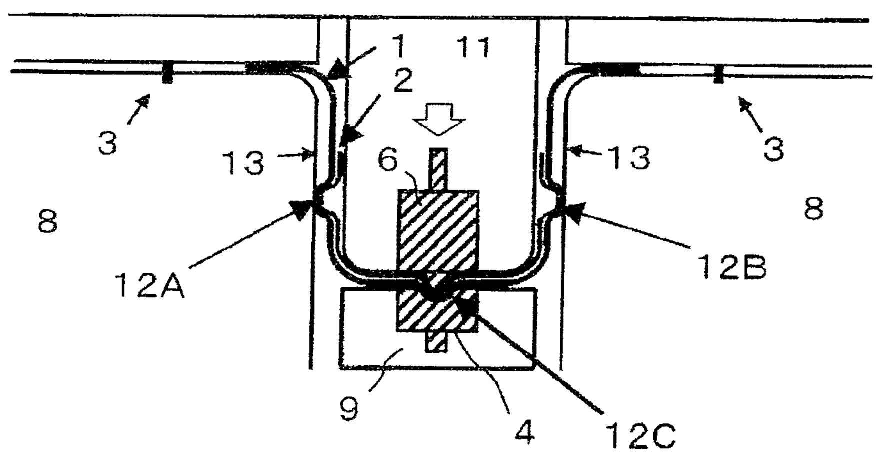


FIG. 3

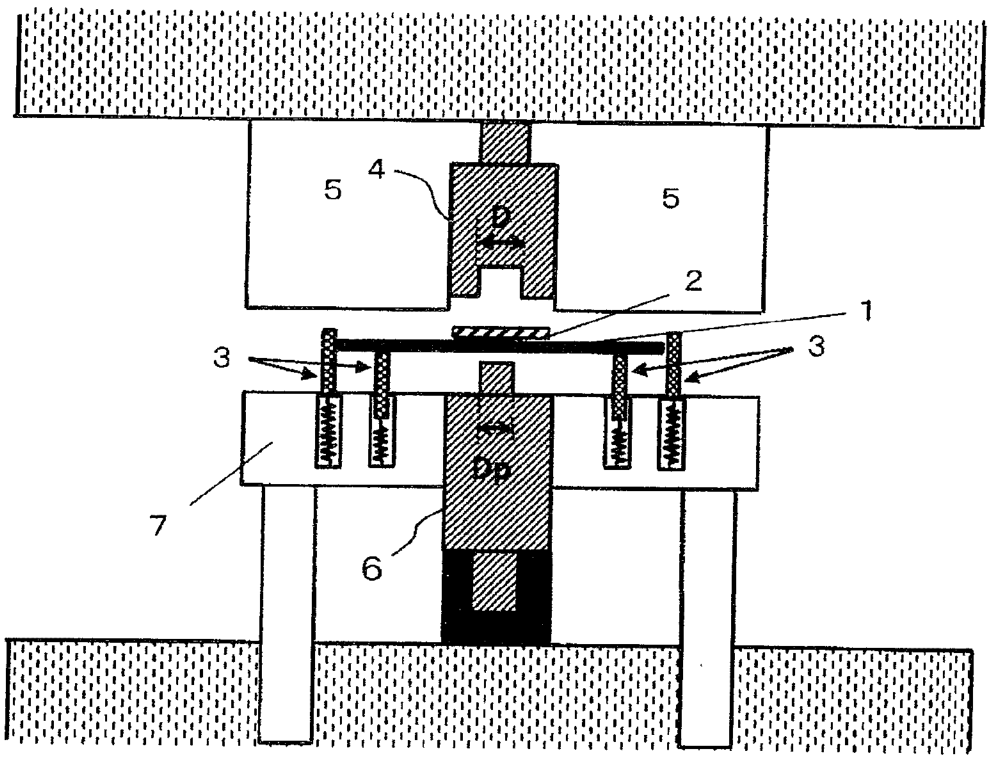


FIG. 4A

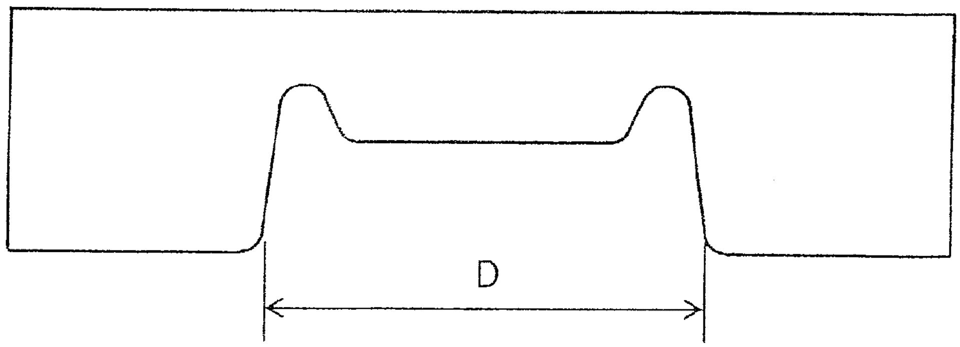


FIG. 4B

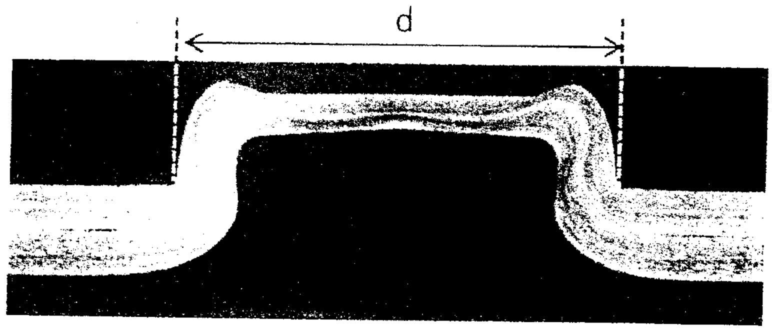


FIG. 5A

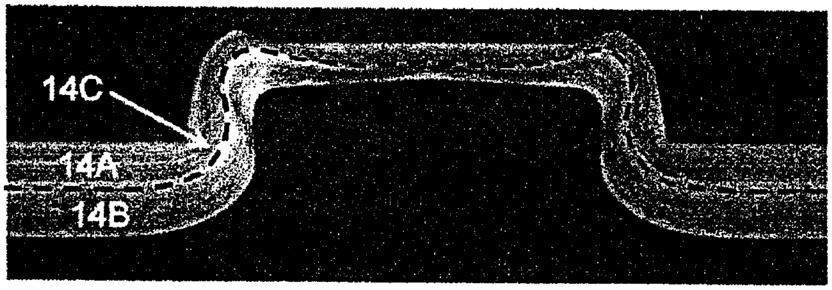


FIG. 5B

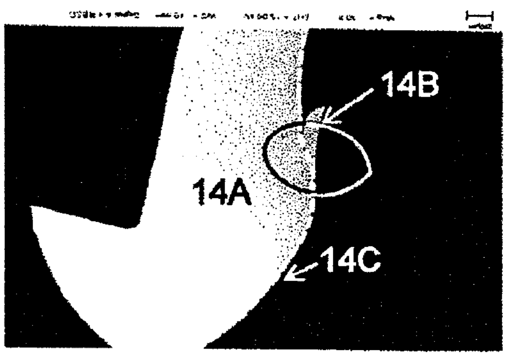


FIG. 5C

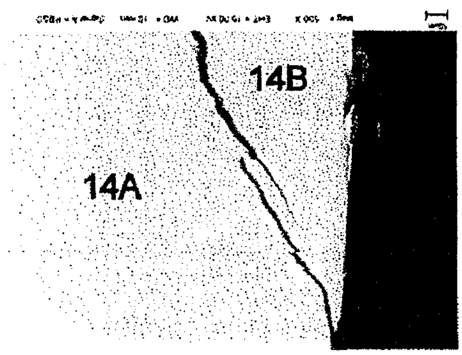
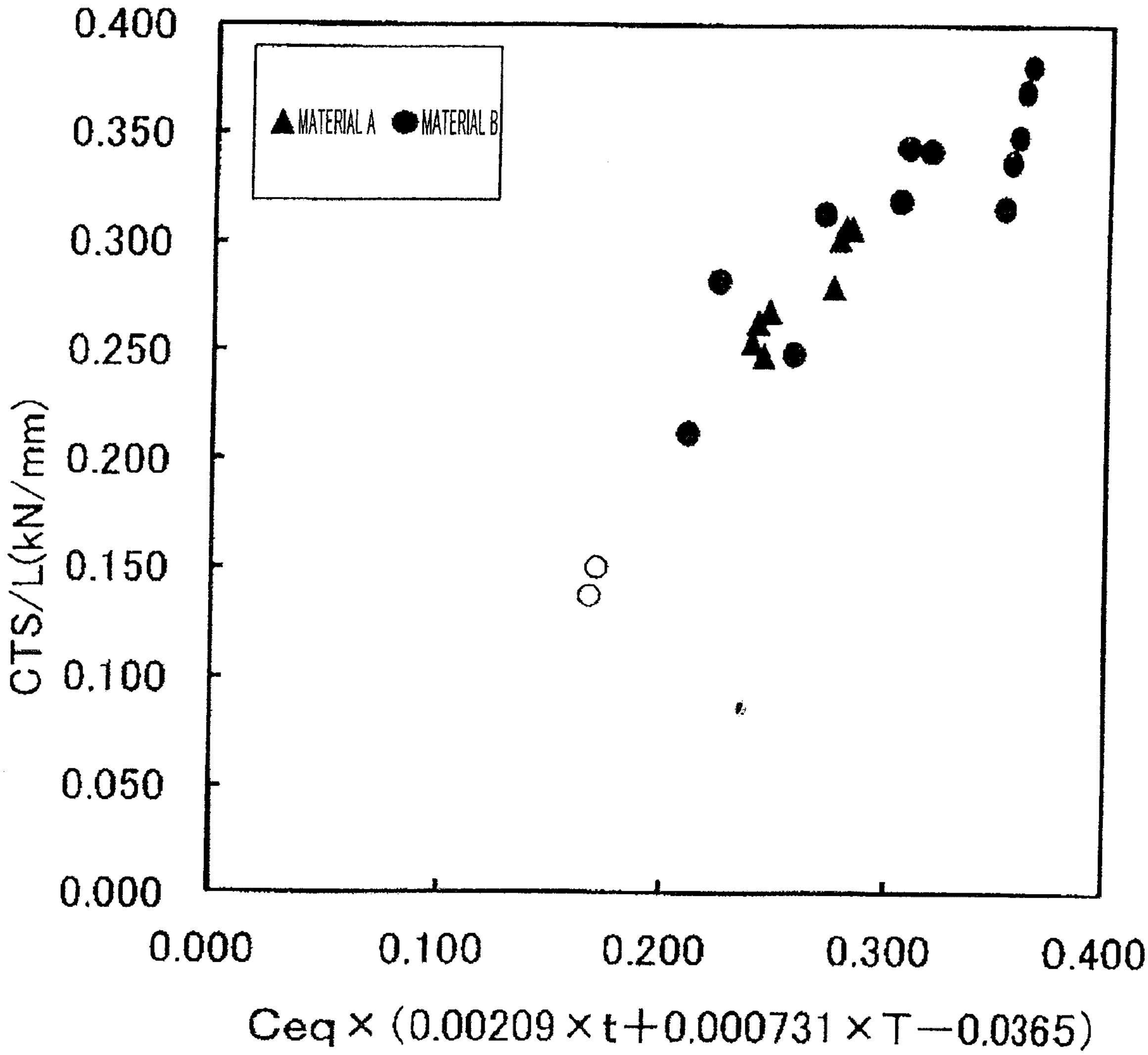
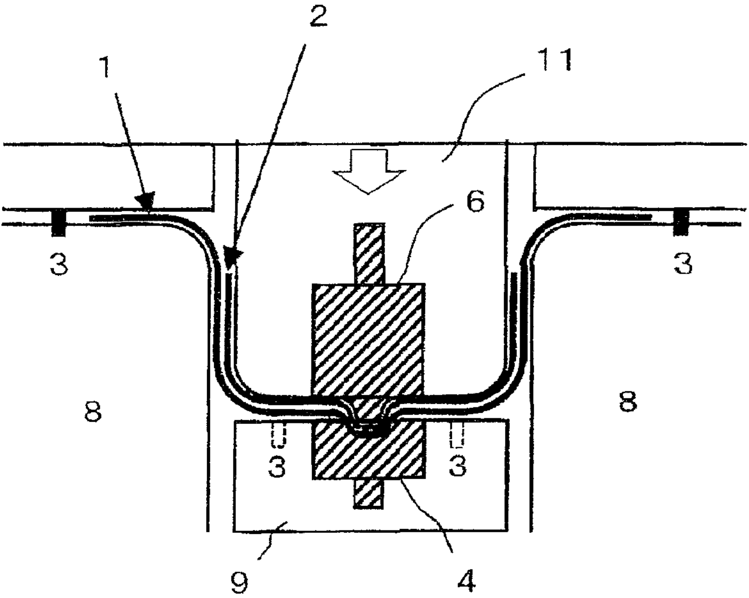


FIG. 6



0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
MATERIAL A
MATERIAL B
CTS/L(kN/mm)
0.000
0.100
0.200
0.300
0.400
Ceq × (0.00209 × t + 0.000731 × T − 0.0365)



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