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(54) **AN ARRANGEMENT OF TOOLS FOR THE FORMING OF SPOT JOINTS AND A METHOD OF THE FORMING OF CLINCHED SPOT JOINTS WITH BETTER STRENGTH PARAMETERS**

(57) An arrangement of tools for the forming of spot joints comprising a punch (ST), a die (MA) and a pressing tool (DO), characterised in that the punch (ST) of the diameter ($\varnothing D_s$) has at its upper end a widening (W) of the width of between 0.1 and 2.0 of the diameter ($\varnothing D_s$) of punch (ST), wherein the angle (α) between the axis of

punch (ST) and the outer surface of widening (W) is 20-70° and widening (W) has an upper curvature (R) of the radius of 1-10 mm and a bottom curvature (F) of the radius of 0.1-5 mm. The invention also relates to a method of the forming of clinched spot joints with better strength parameters

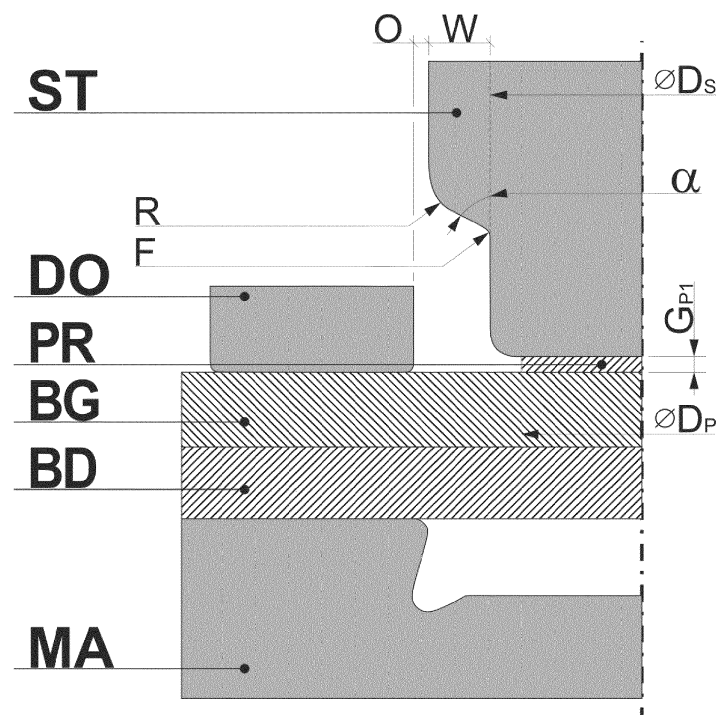


Fig. 1

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Description

[0001] The present invention refers to an arrangement of tools for the forming of spot joints that enables the implementation of a method of the forming of clinched spot joints with better strength parameters.

[0002] According to the existing state of the art, there are various methods that can be used to improve the strength of spot joints. For example, US application US8615859 B2 discloses a method of improving the strength of joints that involves the placing of a first layer of material on a second material, wherein the first layer demonstrates lower ductility than the second layer. The first and second layers are installed between a forming punch and a double-action crimping punch. The crimping punch is pressed into a part of the surface of the first layer, thus creating an opening in the first layer. The forming punch is then pressed into the second layer in the direction opposite to the direction of the punch movement, thus forcing at least a part of the second layer into the opening and forming a ductile joint.

[0003] A method of improving the strength of clinched joints is also disclosed in US application US9937548 B2. The method described in this document consists in the clinching of metal sheets using ultrasound and is used especially with high-strength materials of low deformation characteristics, which are difficult to join via conventional clinching. The joint is made in at least two overlapping components, which are placed between a die and a punch that is present on both sides of a cylinder. The tool applies a compressive force to both objects, while ultrasound energy is applied continuously to at least one of the objects in the joint area. The use of ultrasound during deformation temporarily increases the ductility of at least one of the workpieces, therefore enabling the clinching of highly-durable or thick materials.

[0004] A different method of increasing the durability of clinched joints is to use a self-piercing rivet fastener (Xing et al., 2015). During clinching, the punch presses the rivet in the direction perpendicular to the top surface of the component, forcing it into the die. The force applied to the punch moves the rivet through the top sheet to the bottom sheet. Material from the lower sheet flows into the die and the rivet pin expands to create a mechanical interlock between the sheets. The use of an additional element for the joining of metal sheets increases their static shear strength, which has been experimentally proven on many occasions and using various materials (Chen et al., 2016; Liu et al., 2019).

[0005] Another method of improving the strength of clinched joints is the process of reducing the joint height, i.e. the pressing of a finished joint between a convex die and flat die (Chen et al., 2017). A mechanically blocked height of the clinch allows more material to flow in the radial direction, thereby increasing the thickness of the generated neck and thus the shear strength of the joint.

[0006] Another way of improving the strength of a clinched joint between two metal sheets is to use an adhesive between the bonded metal sheets. The surfaces of the joined parts must be first degreased and roughened, wherein an adhesive is applied in the form of a two-component acrylic glue. Following the completion of clinching, the applied adhesive is allowed to set and is left for about 24 hours at ambient temperature. The performed tests have demonstrated that the addition of an adhesive resulted in an increase in the maximum shear force and energy absorption of a joint consisting of two aluminium sheets (He et al., 2014) and deep-drawn steel and copper alloy sheets.

[0007] A hybrid method of improving the durability of clinched joints involves the simultaneous use of an adhesive and a rivet, as described in application CN110116509 B. According to this method, adhesive is first applied to the surface of one of the joined components and subsequently the components are clinched using a punch and die. Following the completion of the joint, the adhesive is allowed to set and in the next phase the rivet that penetrates the workpiece stack and the adhesive layer is installed. This method produces a high quality clinch joint and minimises the probability of its cracking, splitting or disintegration.

[0008] Solutions that are known to the art can generate a 5 to 45% increase in the shear strength of a clinched joint. Increasing the thickness of the neck generates higher shear strength. Similarly, increasing the width of the undercut increases the transverse tensile strength (pull-out strength). So there are ways to increase one of these parameters, but this always comes at the cost of reducing the other parameter. There is no known method to increase both of these parameters simultaneously. Additionally, we must observe that most of the designed clinch joints are only theoretically subjected to mainly shearing or normal forces. In practice, however, most joints are subjected to combined loads, i.e. consisting of both shearing and pull-out forces, which makes the reduction of strength in any one of these states unacceptable. Additionally, the use of adhesive in joints is an effective and unique method, but it is technologically very demanding and prevents the automation of the assembly process. The use of a punching rivet, on the other hand, carries the risk of damaging both layers of the bonded elements and can produce an unaesthetic and potentially dangerous area with sharp edges and burrs present at the joint.

[0009] The purpose of the invention is to provide a simple method of the simultaneous improvement of both key strength parameters, i.e. the width of the undercut and the thickness of the neck. The aim is to develop a solution that is simple and cost-effective and does not require any additional energy for the heating of any one of the joined components.

[0010] The invention relates to an arrangement of tools for the forming of spot joints comprising a punch, a die and a press, characterised in that the punch of a specified diameter has at its upper end a widening of the width of between 0.1 and 2.0 of the punch diameter, wherein the angle between the punch axis and the outer surface of the widening is 20-70° and the widening has an upper curvature of the radius of 1-10 mm and a bottom curvature of the radius of 0.1-5 mm.

[0011] Preferably, the angle between the punch axis and the outer surface of the widening in the forming tool arrangement according to the invention is 35-55°. This range of values is the most effective in preventing a radial outflow of the material of the top element during the pressing phase and produces the most geometrically favourable joint, i.e. having the thickest neck and widest undercut.

[0012] In another aspect of the invention, the invention also relates to a method for the forming of clinched spot joints having better strength parameters, wherein the method comprises the joining of at least two elements: a top element and a bottom element, characterised in that it comprises the following steps:

a) prior to the forming of the joint, an intermediate element, of the thickness of between 0.4 and 5 mm and of the diameter of between 0.6 and 1.1 of the punch diameter, is placed axially and symmetrically in relation to the punch on the top member,

b) the intermediate element is then formed together with the top element and the bottom element with the use of the arrangement according to the invention,

c) forming is continued until the thickness of the intermediate element is between 20 and 70% of the thickness of this element before the forming process.

[0013] The method according to the invention preferably involves an intermediate element that during step a) has a yield strength of between 5% and 50% of the yield strength of the top element, preferably this yield strength is between 15% and 40%. The implementation of the above range of top member yield strength values allows the yield stress curve of the intermediate member material to be exceeded before the yield stress curve of the top member material is exceeded, thus increasing the contribution of the radial outflow of the intermediate member in all phases of the formation of the joint.

[0014] Equally preferably, in the method according to the invention the top element and bottom element are made of metal sheets, especially steel sheets. The use of steel generates the greatest increase in the strength of joints produced according to the described forming method, in comparison to joints produced using traditional methods.

[0015] The advantage of the solution according to the invention is that it provides a method of forming joints that simultaneously increases the shear strength and the transverse tensile (pull-out) strength of clinched joints under simple and complex load conditions. Shear strength is directly proportional to the thickness of the neck (S), as can be observed during the shearing process, where the fracture of the top element (BG) occurs at the location of the smallest cross-section. Its lower part remains pressed into the bottom element (BD), while its upper part, together with the opening created by the fracture, is subject to unrestricted displacement. Transverse tensile strength, meanwhile, is directly proportional to the width of the undercut (P). This is so because, in the case of normal forces, the joint is usually separated without fracturing the material from the side of the punch or the die. The process of the formation of a joint can be divided into several phases. Once the bottom element (BD) rests on the upper surface of the die (MA) and the position of the top element (BG) relative to the bottom element (BD) is fixed, the punch (ST) moves towards the material. The applied pressure deforms the material and creates an embossing. The process continues, until the bottom sheet comes into contact with the die surface. As a result of the further application of force by the punch (ST), the bottom of the created joint thins out and the material flows out radially. This process is known as pressing. This joint forming process therefore provides a simple way of increasing the width of the undercut (P) by reducing the thickness of the bottom of the joint, but this always takes place at the cost of reducing the thickness of the neck (S). There is no known simple way of simultaneously increasing the width of the undercut (P) and the thickness of the neck (S).

[0016] The object of the invention has been presented in more detail by way of non-limiting embodiments of the invention and in the drawings, in which:

Fig. 1 shows a cross-section of elements used in accordance with the method of improving the strength parameters of clinched spot joints prior to the forming process, with the identification of key elements.

Fig. 2 shows a cross-section of elements used in accordance with the method of improving the strength parameters of clinched spot joints after the completion of the forming process, with the identification of key elements.

Fig. 3 shows a comparison between the cross-section of a joint produced using traditional methods (continuous line) and the cross-section of a joint produced in accordance with the method of improving the strength parameters of clinched spot joints (dashed line),

Fig. 4 shows the value of a normal force as a function of the traverse path obtained during the tensioning of joints produced using different methods ('method according to example 1 (+PR +W)' - the joining of two metal sheets according to method described in example 1 using punch ST with widening W and die MA, with the

application of intermediate element PR; **'method according to example 2 (+PR+W)'** - the joining of two metal sheets according to method described in example 2 using punch ST with widening W and die MA, with the application of intermediate element PR; **'method according to example 3 (+PR+W)'** - the joining of two metal sheets according to method described in example 3 using punch ST with widening W and die MA, with the application of intermediate element PR; **'traditional method (-PR-W)'** - the joining of two metal sheets using traditional punch ST without widening W and using die MA, without the application of intermediate element PR; **'traditional method (+PR -W)'** - the joining of two metal sheets using traditional punch ST without widening W and using die MA with the application of intermediate element PR; **'traditional method (-PR +W)'** - the joining of two metal sheets using punch ST provided with widening W and using die MA without the application of intermediate element PR,

Fig. 5 shows the value of the shearing force as a function of the traverse path obtained during the tensioning of joints produced using different methods - the designation of methods is the same as in the description of fig. 4.

Example 1

[0017] The method of improving the strength parameters of clinched spot joints according to the embodiment of the invention comprises the clinching of top element BG and bottom element BD made of 1.2 mm thick DP600 steel by increasing the key geometrical dimensions of the joint, especially of the thickness of neck S and the width of undercut P. During the first phase, top element BG and bottom element BD are aligned axially against each other and their position is fixed by pressing them against the retaining surface of die MA using pressing tool DO, as shown in fig. 1. In the next phase, intermediate element PR made of plastic PLA characterised by yield strength R_e of 60 MPa, thickness G_{P1} of 0.4 mm and diameter $\varnothing D_P$ of 4.4 mm, is placed above top element BG. Intermediate element PR is then formed together with top plate BG and bottom plate BD using a specially shaped punch of the diameter $\varnothing D_S$ of 4 mm and a die with an internal diameter of 6 mm. The punch, as shown in fig. 2, has an additional widening of the width W of 8 mm, formed at an angle α of 20°, which is curved with an upper radius R of 1 mm and a bottom radius F of 0.1 mm. The forming process is continued until intermediate element PR has the thickness G_{P2} of 0.08 mm.

Example 2

[0018] A method of improving the strength parameters of clinched spot joints as in the first example, wherein intermediate element PR has the thickness G_{P1} of 5 mm and the diameter $\varnothing D_P$ of 2,4 mm and is formed using a specially shaped punch of the diameter $\varnothing D_S$ of 4 mm that has an additional widening of the width W of 0.4 mm, formed at an angle α of 70°, which is curved with an upper radius R of 10 mm and a bottom radius F of 5 mm. The forming process is continued until intermediate element PR has the thickness G_{P2} of 3.5 mm.

Example 3

[0019] A method of improving the strength parameters of clinched spot joints as in the first example, wherein intermediate element PR is made of temper T4 aluminium alloy 2024 with the yield strength R_e of 40 MPa.

Example 4

[0020] Comparative tests were performed to measure the transverse tensile strength and shear strength of spot joints produced using the method according to the invention, as compared to spot joints produced using the traditional method. The results are shown in Table 1.

Table 1. Transverse tensile strength and shear strength of spot joints

Parameter	example 1 method (+PR +W)	example 2 method (+PR +W)	example 3 method (+PR +W)	traditional method (-PR +W)	traditional method (+PR -W)	-traditional method (-PR +W)
Transverse tensile strength	3700 N	4150 N	3800 N	3000 N	3300 N	2500 N

(continued)

Parameter	example 1 method (+PR +W)	example 2 method (+PR +W)	example 3 method (+PR +W)	traditional method (-PR +W)	traditional method (+PR -W)	-traditional method (-PR +W)
Shear strength	5800 N	6200 N	5900 N	4200 N	3600 N	4700 N

[0021] Spot joints generated using embodiments 1 to 3 of the invention had higher strength parameters (transverse tensile strength and shear strength) than joints produced using the traditional method. The highest values of the above parameters were recorded for point joints produced using the method described in the second embodiment of the invention. The application in the third embodiment of the invention of intermediate PR element with a yield strength 20 MPa lower than in the first embodiment resulted in the achievement of higher strength parameters. It was also demonstrated that it is not possible to achieve a simultaneous increase in transverse tensile strength and in shear strength with the use of only intermediate element PR (without the widening W of punch ST), or using only widening W of punch ST (without the use of intermediate element PWR). Additional test results are shown in the form of charts, where fig. 4 refers to transverse tensile strength, while fig. 5 to shear strength.

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Claims

1. An arrangement of tools for the forming of spot joints comprising a punch (ST), a die (MA) and a pressing tool (DO), **characterised in that** the punch (ST) of the diameter ($\varnothing D_S$) has at its upper end a widening (W) of the width of between 0.1 and 2.0 of the diameter ($\varnothing D_S$) of punch (ST), wherein the angle (α) between the axis of punch (ST) and the outer surface of widening (W) is 20-70° and widening (W) has an upper curvature (R) of the radius of 1-10 mm and a bottom curvature (F) of the radius of 0.1-5 mm.
2. The arrangement of forming tools according to claim 1, **characterised in that** angle (α) between the axis of punch (ST) and the outer surface of widening (W) is 35-55°.
3. A method for the forming of clinched spot joints having better strength parameters, wherein the method comprises the joining of at least two elements: a top element (BG) and a bottom element (BD), **characterised in that** it comprises the following steps:

a) prior to the forming of the joint, an intermediate element (PR) of the thickness (G_{P1}) of between 0.4 and 5 mm and of the diameter ($\varnothing D_P$) of between 0.6 and 1.1 of the diameter ($\varnothing D_S$) of punch (ST), is placed axially and symmetrically in relation to punch (ST) on the top member (BG),

b) intermediate element (PR) is then formed together with top element (BG) and bottom element (BD) with the use of the arrangement according to claim 1 or 2,

c) wherein the forming process is continued until the thickness (G_{P2}) of intermediate element (PR) is between 20 and 70% of the thickness (G_{P1}) of element (PR) before the forming process.

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4. The method according to claim 3, **characterised in that** intermediate element (PR) in step (a) has a yield strength R_e of between 5% and 50% of the yield strength of upper element (BG), preferably between 15% and 40%.

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5. The method according to claim 3, **characterised in that** top element (BG) and bottom element (BD) are made of metal sheets, especially steel sheets.

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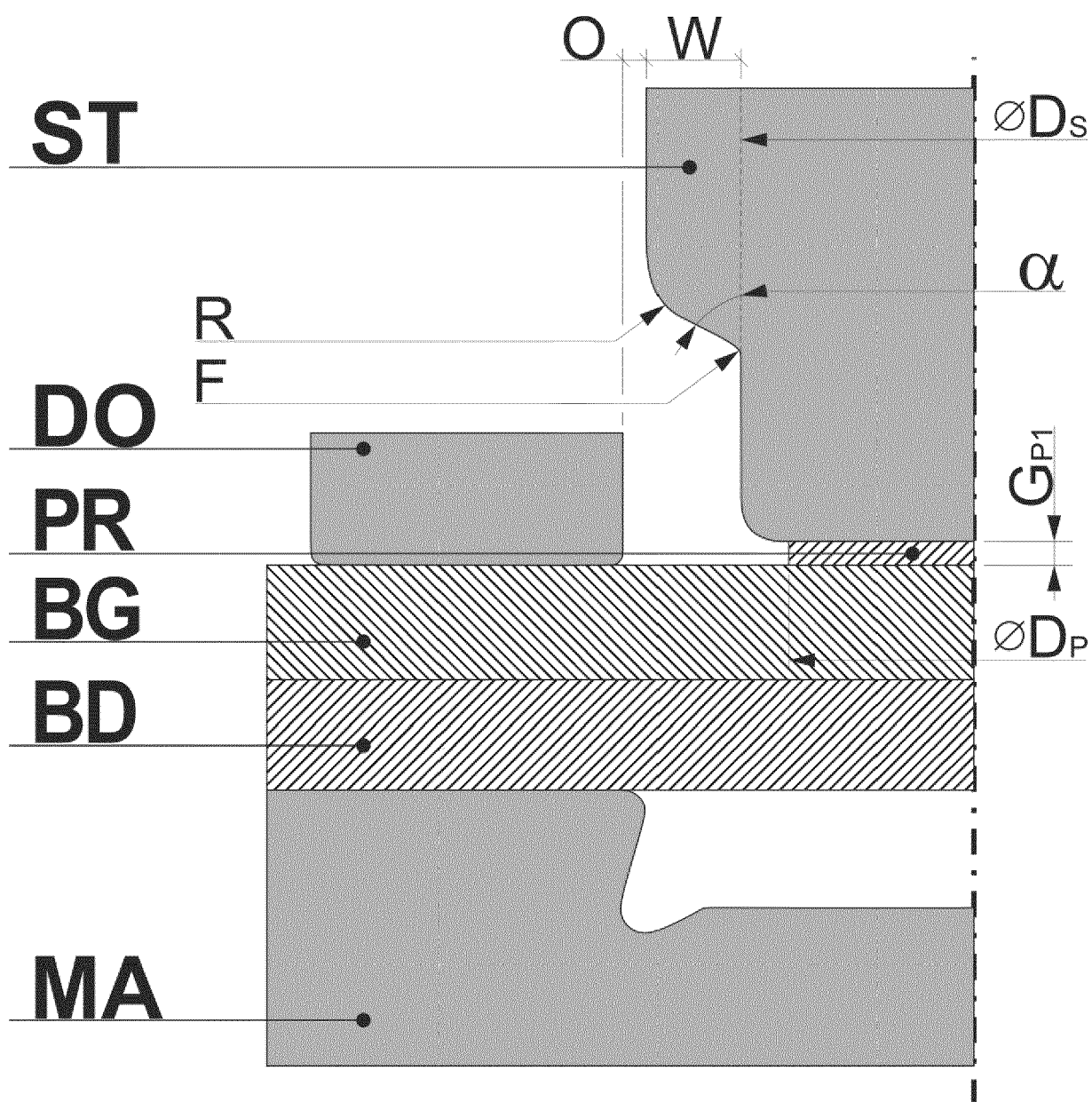


Fig. 1

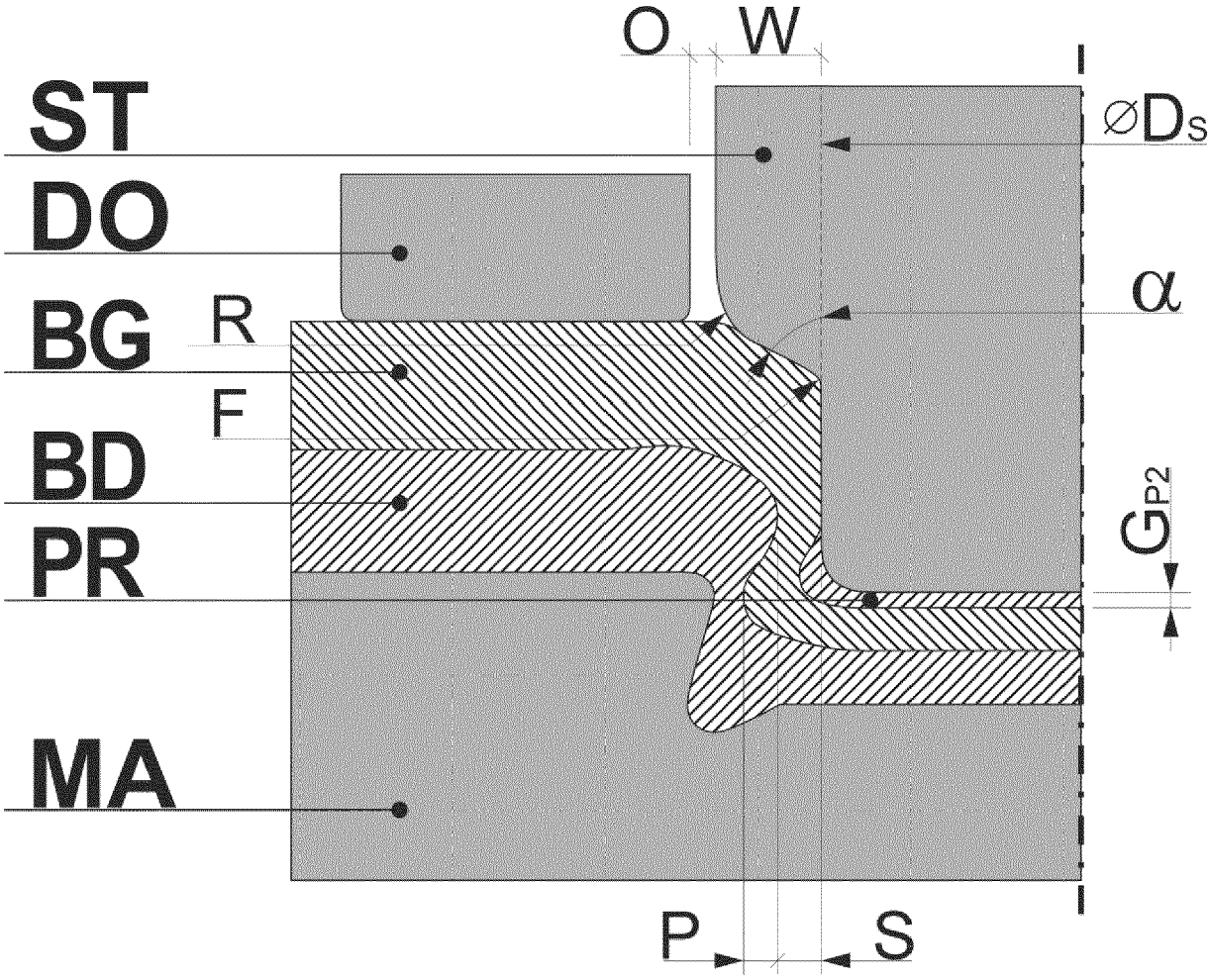


Fig. 2

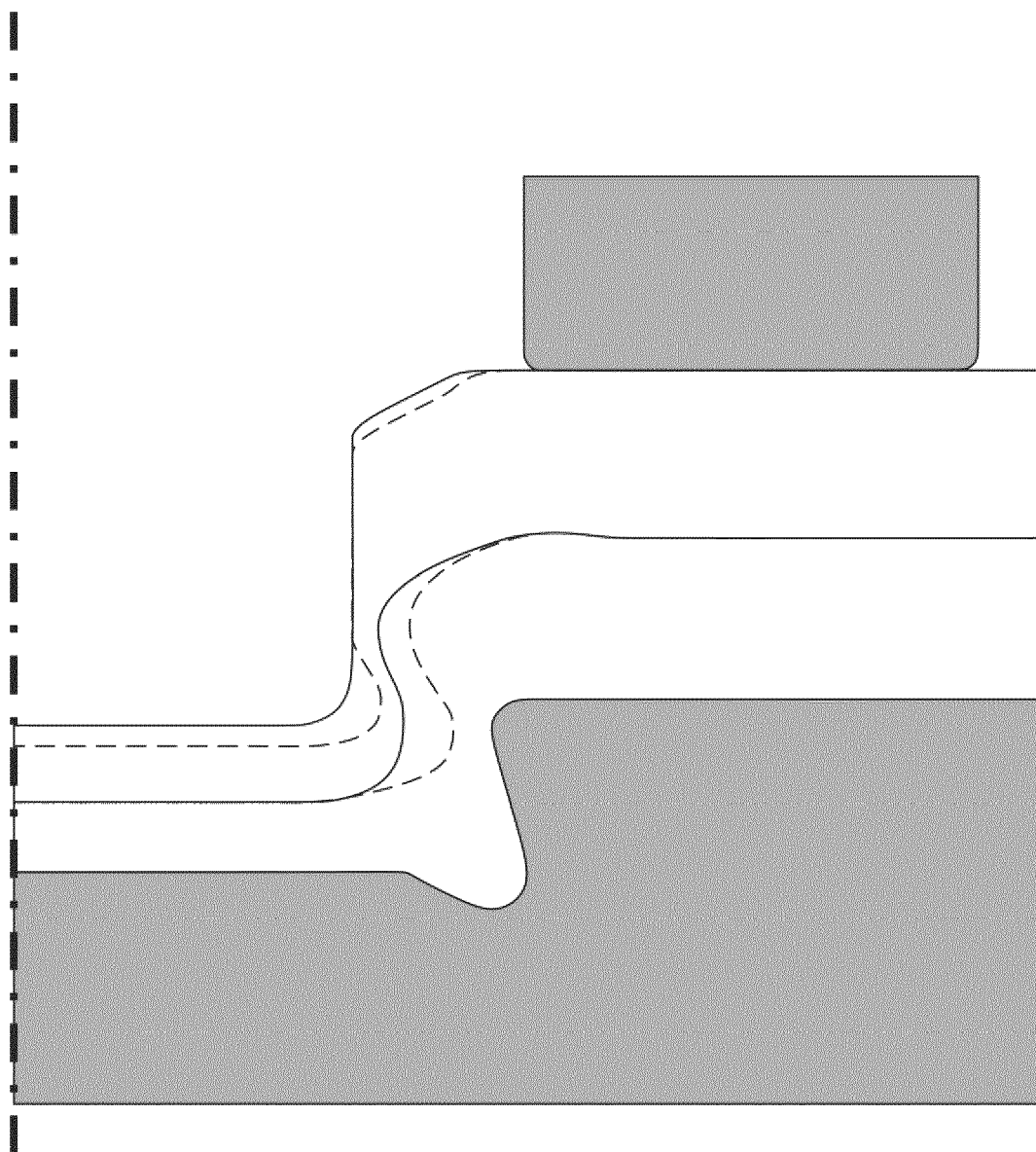


Fig. 3

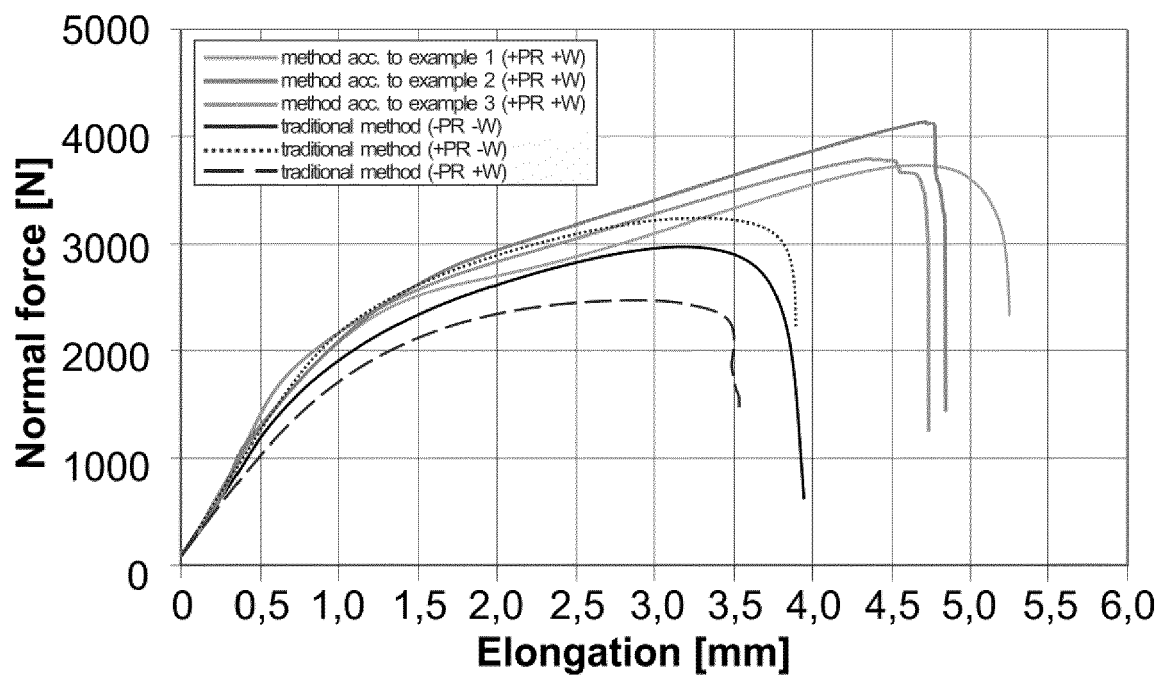


Fig. 4

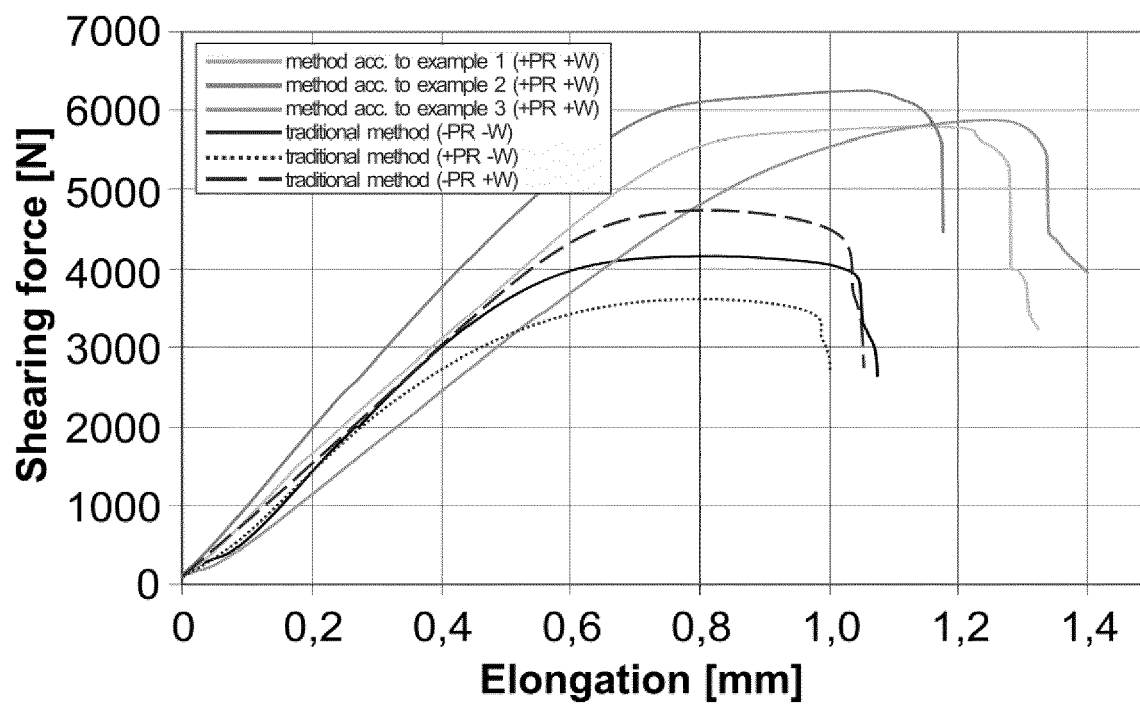


Fig. 5



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