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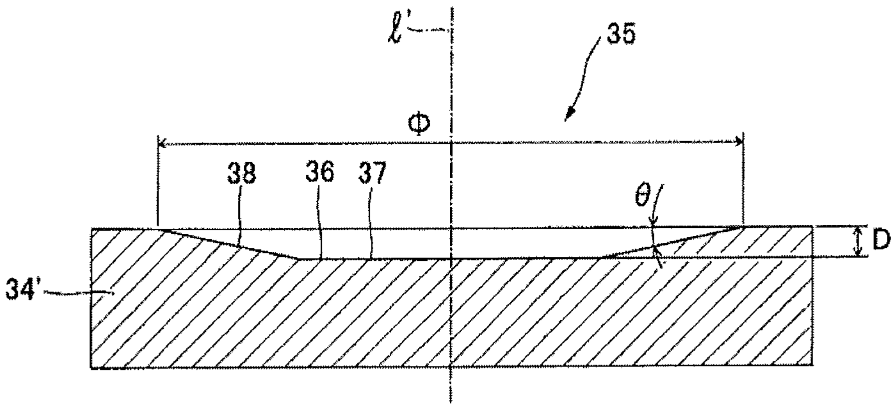
(54) **Die for self-piercing rivet**

(57) To provide a die for a self-piercing rivet fastening device (1) which uses a self-piercing rivet (10) to fasten fastened members (41, 42) with poor malleability formed using a die cast or the like so that the members do not rupture.

The present invention is a die (30; 35) for a self-piercing rivet fastening device (1) having a die (30; 35) and a punch (4) for driving a self-piercing rivet (10) having a large-diameter head (11) and hollow cylindrical legs (12) extending down from the head, and configured so the punch drives the self-piercing rivet (10) into fastened members (41, 42) arranged on top of the die (30; 35), wherein a cavity (31; 36) is formed in the upper surface of the die (30; 35) for receiving portions of the fastened members (41, 42) thrust out by the self-piercing rivet (10) driven by the punch (4), and wherein the cavity (31; 36) is formed as a concave spherical surface having a single radius (R) centered on the central axis (l) of the cavity. Alternatively, the cavity (36) is formed with a bottom surface (37) and a surrounding inclined surface (38), and the angle between the bottom surface and the inclined surface is from 165 to 175°.

[FIG. 7]



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Description

[0001] The present invention relates to a die used in a self-piercing rivet fastening device for fastening a plurality of fastened members using a self-piercing rivet having a large-diameter head and hollow cylindrical legs extending down from the head. More specifically, the present invention relates to a die used to fasten fastened members made of poorly malleable material such as a die cast material.

[0002] A self-piercing rivet is able to be readily joined to a joined member simply by driving in the rivet, even when a hole has not been machined in advance in a fastened member for inserting a bolt or the like. Fig. 1 is an enlarged view of the self-piercing rivet fastening process using a self-piercing rivet fastening device of the prior art. The self-piercing rivet fastening device 1 uses a die 20 and a nose 3 to clamp together two fastened members 41, 42 with strong force (see the arrows). The self-piercing rivet 10 has a large-diameter head 11 and hollow cylindrical legs 12 extending downward from the head 11.

[0003] The die 20 has a cavity 21 in the upper surface, and the bottom surface 22 of the cavity is substantially flat. The self-piercing rivet 10 is driven by a punch 4 into the fastened members 41, 42 arranged on top of the die 20. The tips 13 of the legs in the self-piercing rivet 10 pierce the fastened member 41 adjacent to the punch 4, but remain inside without piercing the fastened member 42 on the receiving side adjacent to the die 20. The tips of the legs 12 of the self-piercing rivet 10 are deformed outward in the radial direction from the die 20. The fastened members 41, 42 are connected by the head 11 and the legs 12 opened inside the fastened member 42. In Fig. 1, the bottom surface 22 of the cavity is formed so as to be substantially flat. A protrusion with a different shape is provided in the center of the cavity 21 and protrudes towards the punch.

[0004] A self-piercing rivet is suitable for aluminum body panels unfit for riveting. As vehicle bodies have become lighter and aluminum bodies more widely used, the demand for self-piercing rivets has increased. Because self-piercing rivets pierce the fastened member on the punch side but remain inside and do not pierce the fastened member 42 on the receiving side adjacent to the die 20, a rivet piercing hole is not formed in the surface of the fastened member 42 on the receiving side. As a result, the sealing properties of the fastened member 42 on the receiving side are not compromised, and the fastened member retains its external appearance.

[0005] When fastened members 41, 42 with poor malleability such as die cast materials are fastened with a self-piercing fastening device using a conventional die 20, the tips of the legs 12 of a self-piercing rivet 10 driven by the punch pierce and push into the fastened members 41, 42, which are deformed by the cavity 21 of the die 20. When this occurs, the fastened members 41, 42 cannot resist plastic deformation and sometimes rupture. The fastened member 42 on the receiving side is more likely to rupture.

[0006] In Patent Document 1, joined members with low ductility are joined using a self-piercing rivet. In Patent Document 1, the joined members are heated where the self-piercing rivet is driven into the members. This can prevent cracking when a rivet is driven into joined members with low ductility. However, a heating device is needed to heat the joined members in the joining method of Patent Document 1. This increases the amount of time needed to perform the joining process.

[0007] Patent Document 2 discloses a method for fastening thin-plate materials using a self-piercing rivet. In the method of Patent Document 2, a through-hole is formed in at least one of the joined members or the member is partially thinned to facilitate fastening with a rivet. Because a through-hole or countersink has to be formed in the joined portion of a fastened member in the fastening method of Patent Document 2, the machining of the fastened members is more complicated. Because a hole has to be formed in a fastened member in Patent Document 2, the advantages of using a self-piercing rivet are undermined.

[0008] Joined members can be easily joined using a self-piercing rivet when a hole is formed in the fastened members. However, the fastened member on the die side sometimes ruptures when fastened using a self-piercing rivet if the fastened member is a fastened member with poor malleability formed using a die cast or the like. The joining methods in Patent Documents 1-2 using self-piercing rivets can be made less likely to rupture a fastened member, but they require addition operations during the fastening process, and this complicates an otherwise simple fastening operation. Therefore, a self-piercing rivet fastening device and fastening method are desired which can prevent the rupture of fastened members when poorly malleable fastened members are fastened using a self-piercing rivet.

[0009] [Patent Document 1] Published Unexamined Patent Application No. JP 2006-7266; [Patent Document 2] Japanese Translation of Published PCT Application No. WO 10-501744.

[0010] The object of the present invention is to provide a die for a self-piercing rivet fastening device which is able to use a self-piercing rivet to fasten fastened members with poor malleability so that the members do not readily rupture.

[0011] In order to achieve this object, the present authors discovered that the deformation of fastened members could be minimized and the rupturing of fastened members made less likely by reducing the depth of the die cavity, forming a concave spherical surface with a single radius R in the cavity, or forming a cavity with a bottom surface and a surrounding inclined surface in which the angle between the inclined surface and the bottom surface is from 165 to 175°.

[0012] One aspect of the present invention is a die for a self-piercing rivet fastening device having a die and a punch for driving a self-piercing rivet having a large-diameter head and hollow cylindrical legs extending down from the head, and configured so the punch drives the self-piercing rivet into fastened members arranged on top of the die, wherein a cavity is formed in the upper surface of the die for receiving portions of the fastened members thrust out by the self-piercing rivet driven by the punch, and wherein the cavity is formed as a concave spherical surface having a single radius R centered on the central axis of the cavity.

[0013] When the cavity is formed with a spherical surface having a single radius and the bottom surface of the cavity is smoothly continuous from the central portion to the periphery, the fastened members are not bent at an acute angle when received by the cavity, and deformation of the fastened members can be minimized. As a result, the fastened members are less likely to rupture.

[0014] Another aspect of the present invention is a die for a self-piercing rivet fastening device having a die and a punch for driving a self-piercing rivet having a large-diameter head and hollow cylindrical legs extending down from the head, and configured so the punch drives the self-piercing rivet into fastened members arranged on top of the die, wherein a cavity is formed in the upper surface of the die for receiving portions of the fastened members thrust out by the self-piercing rivet driven by the punch, wherein the cavity is formed having a round bottom surface in the central portion of the cavity, and an inclined surface on the outer periphery between the bottom surface and the upper surface of the die, and wherein the inclination of the inclined surface from the upper surface of the die is from 7 to 15°.

[0015] When the cavity is formed with a round bottom surface surrounded by an inclined surface with a gentle incline, and the bottom surface and the inclined surface are continuous at a gentle obtuse angle, the fastened members are not bent at an acute angle when received by the cavity, and deformation of the fastened members can be minimized. As a result, the fastened members are less likely to rupture.

[0016] Preferably, when the self-piercing rivet is driven into the fastened members, the legs pierce the fastened member on the punch side, the tips of the legs push downward through the fastened member on the receiving side adjacent to the die, the die receives the fastened member on the receiving side deforming the tips of the legs so as to expand outward radially and remain inside the die without piercing the fastened member on the receiving side adjacent to the die, and the plurality of fastened members are fastened to each other by the head and the expanded legs of the self-piercing rivet.

[0017] Preferably, the upper surface of the die and the upper portion of the cavity are continuous at an obtuse angle. This can reduce deformation of the fastened members where they come into contact with the boundary region between the upper surface of the die and the upper end portion of the cavity.

[0018] The depth from the upper surface of the die to the central portion of the cavity is preferably from 0.5 to 1.5 mm, and more preferably from 0.5 to 0.9 mm. When the cavity is shallower than 0.5 mm, the self-piercing rivet is not driven sufficiently into the fastened members. When the cavity is deeper than 1.5 mm, the deformation of the fastened members is insufficient.

[0019] The diameter of the cavity in the upper surface of the die is preferably from 10 to 18 mm, and more preferably from 11 to 15 mm. When the diameter of the cavity is less than 10 mm, it is difficult to expand the legs of the self-piercing rivet inside the cavity. When the diameter of the cavity is greater than 18 mm, the legs of the self-piercing rivet cannot hold the portion of the fastened members surrounding the pierced portion, and the fastened members are difficult to fasten using a self-piercing rivet.

[0020] The present invention is able to reduce deformation of fastened members and make the rupturing of poorly malleable fastened members less likely compared to a situation in which a self-piercing rivet is fastened using a conventional die. As a result, a die for a self-piercing rivet fastening device can be provided that is able to use a self-piercing rivet to readily fasten fastened members with poor malleability.

[0021] It will be understood that the features of the invention mentioned above and those yet to be explained below can be used not only in the respective combination indicated, but also in other combinations or in isolation, without leaving the scope of the present invention. Exemplary embodiments of the invention are explained in more detail in the following description and are represented in the drawings, in which:

Fig. 1 shows an enlarged view of the self-piercing rivet fastening process using a self-piercing rivet fastening device of the prior art.

Fig. 2 shows a cross-sectional view of the die in the first embodiment of the present invention.

Fig. 3 shows an enlarged cross-sectional view of the dotted line portion A in Fig. 2.

Fig. 4A shows an enlarged cross-sectional view of fastened members before being fastened by a self-piercing rivet using a die of the prior art.

Fig. 4B shows an enlarged cross-sectional view of fastened members after being fastened by a self-piercing rivet using a die of the prior art.

Fig. 5A shows an enlarged cross-sectional view of fastened members before being fastened by a self-piercing rivet using the die in the first embodiment of the present invention.

Fig. 5B shows an enlarged cross-sectional view of fastened members after being fastened by a self-piercing rivet using the die in the first embodiment of the present invention.

Fig. 6 shows a graph plotting the relationship between cavity diameter φ, depth D, and spherical surface radius R in a die according to the first embodiment of the present invention.

Fig. 7 shows an enlarged cross-sectional view of the dotted line portion A in Fig. 2 of a die according to the second embodiment of the present invention.

Fig. 8 shows a diagram of a device used to measure load and displacement (a), and a graph showing the relationship between load and displacement (b).

Fig. 9 shows a cross-sectional view of the cavity portion of a conventional die used in testing (a), and a cross-sectional view of the cavity portion of a die according to a first embodiment of the present invention (b).

[0022] The following is an explanation with reference to Fig. 2 and Fig. 3 of the die for a self-piercing rivet in the first embodiment of the present invention. The self-piercing rivet fastening device uses the die 30 in the first embodiment of the present invention instead of a conventional die 20. The self-piercing rivet 10 is driven by the punch 4 into fastened members 41, 42 arranged on top of the die 30. In every other respect, the self-piercing rivet fastening device is identical to the device of the prior art shown in Fig. 1.

[0023] Fig. 2 is a cross-sectional view of the die 30 in the first embodiment of the present invention being used in a self-piercing rivet fastening device 1. The die 30 is symmetrical around the central axis, and has a column-shaped base 33 and a column-shaped machined portion 34 with an outer diameter greater than that of the base 33. The upper portion of the machined portion 34 is made of a hard material such as high-speed tool steel to deform the legs 12 of the rivet 10. A cavity 31 is formed in the upper surface of the machined portion 34 to deform the legs 12 of the self-piercing rivet 10. The self-piercing rivet 10 is made of a bendable material such as a boron-copper alloy or a chromium-molybdenum-copper alloy, and the outer diameter of the legs 12 is from 3 to 5.5 mm.

[0024] Fig. 3 is an enlarged cross-sectional view of the dotted line portion A of the die 30 in Fig. 2. The cavity 31 is symmetrical with respect to the central axis I, and is formed with a concave spherical surface with a single radius R centered on the central axis I. The diameter φ of the cavity 31 in the upper surface of the machined portion 34 is from 10 to 18 mm, and the depth D from the upper surface of the machined portion 34 to the lowest point in the bottom surface of the cavity 31 is from 0.5 to 1.5 mm. When the cavity 31 is relatively shallow, deformation of the fastened members 41, 42 can be minimized. As a result, rupture of the fastened members is less likely to occur.

[0025] The diameter of the cavity 31 in the die 30 should be at least 7 mm greater than the outer diameter of the legs 12 of the self-piercing rivet. When the outer diameter of the legs 12 of the self-piercing rivet 10 is 3 mm and the diameter of the cavity 31 is less than 10 mm, it is difficult to expand the legs 12 of the self-piercing rivet 10 inside the cavity. When the diameter of the cavity is greater than 18 mm, the self-piercing rivet 10 cannot hold the portion of the fastened members 41, 42 surrounding the pierced portion, and the fastened members are difficult to fasten.

[0026] The following is an explanation with reference to Fig. 4A and Fig. 4B of the situation when fastened members 41, 42 are fastened with a self-piercing rivet 10 using a die 20 of the prior art having a cavity 21 with a flat bottom surface 22. This is followed by a comparative explanation with reference to Fig. 5A and Fig. 5B of the situation when fastened members 41, 42 are fastened with a self-piercing rivet 10 using the die 30 in the first embodiment of the present invention which includes a cavity 31 having a spherical surface with a single radius R. Fig. 4A is an enlarged cross-sectional view of fastened members 41, 42 before being fastened by a self-piercing rivet 10 using a die 20 of the prior art. The die 20 has a cavity 21 in the upper surface. The bottom surface 22 of the cavity 21 is substantially flat, and the side surface 23 is substantially cylindrical. The self-piercing rivet 10 has a large-diameter head 11 and hollow cylindrical legs 12 extending downward from the head 11. The fastened members 41, 42 are stacked on the upper surface of the die 20, the area surrounding the fastened portion is pushed down by a nose (not shown), and the leg tips 13 of the self-piercing rivet 10 make contact with the fastened portion.

[0027] Fig. 4B is an enlarged cross-sectional view of the fastened members 41, 42 after being fastened by the self-piercing rivet 10 using the die 20 of the prior art. When the self-piercing rivet 10 has been driven by the punch 4, the punch 4 causes the legs 12 to pierce the fastened member 41 on the punch side and to plastically deform the fastened member 42 on the receiving side. The legs 12 cause the fastened member 42 to be thrust downward, and the portion of the fastened member 42 thrust downward is received inside the cavity 21, and a portion of the lower surface of the fastened member 42 makes contact with the bottom surface 22 of the cavity 21. Because the fastened member 42 can no longer move vertically, the legs 12 of the self-piercing rivet 10 push outward in the radial direction in the fastened member 42, and are deformed so as to extend outward in the radial direction. The tips 13 of the legs do not pierce the fastened member 42 adjacent to the die 20 and remain inside. The fastened members 41, 42 are connected to each other by the head 11 and the expanded legs 12 inside the fastened member 42.

[0028] Because the curvature in the boundary region between the bottom surface 22 and side surface 23 of the die 20 can change greatly, the amount of deformation in the portion of the fastened member 42 denoted by 42a is great, and a rupture is more likely to occur. Also, because the boundary region between the upper surface of the die 20 and the side surface 23 of the cavity 21 is at nearly a right angle, a rupture is more likely to occur in the portion of the fastened member 42 denoted by 42b when it makes contact with this angle.

[0029] Next, the situation when fastened members 41, 42 are fastened by a self-piercing rivet 10 using the die 30 in the first embodiment of the present invention will be explained with reference to Fig. 5A and Fig. 5B. Fig. 5A is an enlarged cross-sectional view of fastened members 41, 42 before being fastened by a self-piercing rivet 10 using the die 30 in the first embodiment of the present invention. The die 30 has a cavity 31 formed with a concave spherical surface having a single radius R. The fastened members 41, 42 are set on top of the die 30, the outer periphery of the fastened portion is pressed by the nose (not shown), and the leg tips 13 of the self-piercing rivet 10 make contact with the surface of the fastened member 41.

[0030] Fig. 5B is an enlarged cross-sectional view of fastened members 41, 42 after being fastened by the self-piercing rivet 10 using the die 30. When the self-piercing rivet 10 has been driven by the punch 4, the punch 4 causes the legs 12 to pierce the fastened member 41 on the punch side and to plastically deform the fastened member 42 on the receiving side. The legs 12 cause the fastened member 42 to be thrust downward, and the portion of the fastened member 42 thrust downward is received inside the cavity 31 of the die 30, and a portion of the lower surface of the fastened member 42 makes contact with the bottom surface 32 of the cavity 31. Because the fastened member 42 can no longer move vertically, the legs 12 of the self-piercing rivet 10 push outward in the radial direction in the fastened member 42, and are deformed so as to extend outward in the radial direction. The tips 13 of the legs do not pierce the fastened member 42 adjacent to the die 30 and remain inside. The fastened members 41, 42 are connected to each other by the head 11 and the expanded legs 12 inside the fastened member 42.

[0031] In the die 30 of the first embodiment of the present invention, the bottom surface 32 of the cavity 31 is a spherical surface with a single radius R. There is no boundary region between the bottom surface 32 of the cavity 31 and the side surface. Instead, it is smooth and continuous. Also, the cavity 31 is shallower in the portion where the legs 12 of the rivet 10 bite into the fastened member 42. As a result, there is no sharp curve in the portion of the fastened member 42 denoted by 42a', and there is little displacement. Also, the boundary region between the upper surface of the die 30 and the cavity 31 has an obtuse angle. As a result, the portion of the fastened member 42 denoted by 42b' is less likely to rupture when it comes into contact with the boundary region between the upper surface of the die 30 and the cavity 31.

[0032] In order to provide the cavity 31 of the die 30 in the first embodiment of the present invention with an optimum shape, variations in the diameter φ of the cavity 31, the depth D of the cavity, and the radius R of the spherical surface were studied with respect to a single-radius R cavity 31 for the die 30. The radius R of the spherical surface of the cavity 31 was calculated when the diameter φ of the cavity 31 was changed at 1 mm intervals in the 10 to 18 mm range, and the depth D of the cavity was changed at 0.1 mm intervals in the 0.5 to 1.5 mm range. Fig. 6 is a graph plotting the calculation results for the radius R when the diameter φ was changed between 10 and 18 mm, and the depth D was changed between 0.5 and 1.5 mm. The radius R became larger as the diameter φ became larger, and the radius R became larger as the depth D became greater.

[0033] The following is an explanation of the die 35 in the second embodiment of the present invention. Fig. 7 shows the die 35 in the second embodiment, and is an enlarged cross-sectional view of the dotted line portion A of the machined portion 34' of the die 35 in Fig. 2. The cavity 36 is axially symmetrical with respect to the central axis l', has a round bottom surface 37 centered on the central axis l' and parallel to the upper surface of the die 35, and has an inclined surface 38 surrounding the bottom surface 37. The inclined surface 38 has a truncated conical shape. The outer diameter φ of the inclined surface 38 of the cavity 36 at the upper surface of the die 35 is from 11 to 15 mm, and the depth D from the upper surface of the die 35 to the bottom surface 37 of the cavity 31 is from 0.5 to 0.9 mm. The angle of inclination θ of the inclined surface 38 from the upper surface of the die 35 is from 7 to 15° (the angle of the bottom surface 37 and the inclined surface 38 is from 165 to 175°, preferably from 165° to 173°).

[0034] In the die 35 in the second embodiment, the bottom surface 37 of the cavity 36 is round and flat, and is connected to the surrounding inclined surface 38 at an obtuse angle. As a result, the portion of the fastened member 42 making contact near the boundary between the bottom surface 37 and the inclined surface 38 is not bent sharply and is not deformed very much. As a result, a rupture is less likely to occur. The boundary between the upper surface of the die 35 and the inclined surface 38 is also an obtuse angle. As a result, a rupture is also less likely to occur in the portion of the fastened member 42 making contact with the boundary between the upper surface of the die 35 and the inclined surface 38.

[0035] (Measuring Amount of Displacement When Rupturing of Fastened member Occurs)

A test was conducted to determine the amount of displacement when the fastened member 42 on the receiving side ruptures at the diameter φ of the die 30 in the first embodiment of the present invention. The rivet 10 used in the test was made of a boron-copper alloy, and the diameter of the legs 12 was 3.35 mm. The fastened member 41 on the punch side was a mild steel plate (SCGA270-45) with a thickness of 0.65 mm, and the fastened member 42 on the receiving side was a heat-treated aluminum die casting material with a thickness of 2.4 mm. Fig. 8 (a) is a schematic diagram showing the measurement method for the load and amount of displacement. As shown in Fig. 8 (a), the fastened members 41, 42 were stacked on top of the die 20, and the rivet 10 was placed in a position above the cavity 21 of a conventional die 20. The punch 4 was placed on top of the rivet 10. In this test, a conventional die 20 with a flat bottom surface was used, and the depth of the die was sufficiently greater than the rupture depth of the fastened member 42 so that the amount of displacement could be measured when ruptured by the die. The punch 4 was lowered at a rate of 1 mm/min, and the load applied by the punch 4 and the displacement of the punch 4 is measured at this time.

[0036] Fig. 8 (b) is a graph showing the relationship between load and displacement. When the load had been reduced as indicated by point B, the occurrence of a rupture in the fastened member 42 was estimated, and the driving of the punch was stopped. At this time, the displacement of the fastened member 42 on the receiving side was measured using a micrometer.

[0037] Five dies 30 were prepared with different diameters φ for the cavity 31, and the test was conducted in which the number of test samples was n = 5. The amount of displacement in the fastened member 42 at the time of rupture was measured. The results are shown in Table 1. The amount of displacement in the fastened member 42 is the average value of the five test samples. Because deformation of the fastened members 41, 42 can be suppressed by using a die 30 with cavity 31 having a shallower depth D, the depth was set at 0.6 mm. This is the same depth as a conventional die.

[0038]

Table 1

Diameter φ (mm) of Cavity 31	Displacement of Fastened Member 42 (mm)	Average Displacement (mm)
7.0	0.67	0.65
7.3	0.70	
7.5	0.63	
7.8	0.64	
8.0	0.62	

[0039] From the results of the test, it is clear that the fastened member 42 experiences hardly any displacement leading to rupture when the diameter φ of the cavity 31 in the die 30 is in the range from 7.0 to 8.0 mm.

[0040] (Rupture Test When Fastened Using a Conventional Die and the Die in the First Embodiment of the Present Invention)

In this test, fastened members were fastened by a self-piercing rivet 10 using a conventional die 20 with a cavity 21 having a cylindrical side surface 23 and a flat bottom surface 22, and the die 30 in the first embodiment of the present invention with a cavity 31 whose bottom surface 32 is formed with a single radius R. This test was conducted to determine whether or not a rupture would occur in the fastened members 41, 42.

[0041] Fig. 9 (a) is a cross-sectional view of the cavity 21 portion of the conventional die 20 used in the test, and Fig. 9 (b) is a cross-sectional view of the cavity 31 portion of the die 30 in the first embodiment of the present invention used in the test. The depth of both cavity 21 and cavity 31 was 0.60 mm. The fastened member 41 on the punch side was a mild steel plate (SCGA270-45) (thickness: 0.65 mm), and the fastened member 42 on the receiving side was a heat-treated aluminum die casting material (thickness: 2.4 mm). These were fastened together using a self-piercing rivet 10. The self-piercing rivet 10 was the same rivet used in the test shown in Table 1 above.

[0042] When fastened using the conventional die 20 with a flat bottom surface 22 shown in Fig. 9 (a), the fastened member 42 on the receiving side did not rupture in the portion where it made contact with the bottom surface 22 of the die 20, but it did rupture in the portion near the boundary region between the bottom surface 22 of the die 20 and the side surface 23. Because the boundary portion between the bottom surface 22 of the die 20 and the side surface 23 has significant curvature, the amount of displacement on the fastened member 42 was great in this portion. Because the boundary portion between the upper surface of the die 20 and the side surface 23 of the cavity 21 was nearly at a right angle, a rupture is believed to be more likely to occur when the fastened member 42 makes contact with this portion.

[0043] When fastened using the die 30 in the first embodiment of the present invention shown in Fig. 9 (b) which has a bottom surface 32 with a single radius R, the fastening member 42 on the receiving side did not rupture. Because the bottom surface 32 of the cavity 31 is a spherical surface with a single radius R, there is no boundary region between the bottom surface and the side surface of the cavity 31. Also, the cavity 31 is shallow on the periphery. As a result, very little displacement occurs in the fastened member 42 and a rupture is less likely to occur. Also, the boundary region between the upper surface of the die 30 and the cavity 31 is an obtuse angle. As a result, a rupture is less likely to occur in the portion making contact with the boundary region between the upper surface of the die 30 and the cavity 31.

[0044] When aluminum die cast fastened members with poor malleability are fastened by a self-piercing rivet using a die in an embodiment of the present invention, very little deformation occurs in the fastened members, and a rupture in the fastened members is unlikely to occur.

[Key to text in Figures]

[0045]

1: Self-Piercing Rivet Fastening Device
3: Nose
4: Punch
10: Self-Piercing Rivet
11: Head
12: Leg
13: Leg Tip
20: Conventional Die
21: Cavity
22: Bottom Surface
23: Side Surface
30: Die in First Embodiment of the Present Invention
31: Cavity
32: Cavity Bottom Surface
33: Base
34: Machined Portion
35: Die in Second Embodiment of the Present Invention
36: Cavity
37: Bottom Surface
38: Inclined Surface
41: Fastened Member (Punch Side)
42: Fastened Member (Receiving Side)

Claims

1. A die (35) for a self-piercing rivet fastening device (1) having a die (35) and a punch (4) for driving a self-piercing rivet (10) having a large-diameter head (11) and hollow cylindrical legs (12) extending down from the head (11), and configured so that the punch (4) drives the self-piercing rivet (10) into fastened members (41, 42) arranged on top of the die (35),
wherein a cavity (36) is formed in the upper surface of the die (35) for receiving portions of the fastened members (41, 42) thrust out by the self-piercing rivet (10) driven by the punch (4), wherein the cavity (36) is formed having a round bottom surface (37) in the central portion of the cavity (36), and an inclined surface (38) on the outer periphery between the bottom surface (37) and the upper surface of the die (35), and wherein the inclination (θ) of the inclined surface (38) from the upper surface of the die (35) is from 7 to 15°.

2. A die (30) for a self-piercing rivet fastening device (1) having a die (30) and a punch (4) for driving a self-piercing rivet (10) having a large-diameter head (11) and hollow cylindrical legs (12) extending down from the head (11), and configured so that the punch (4) drives the self-piercing rivet (10) into fastened members (41, 42) arranged on top of the die (30),
wherein a cavity (31) is formed in the upper surface of the die (30) for receiving portions of the fastened members (41, 42) thrust out by the self-piercing rivet (10) driven by the punch (4), and wherein the cavity (31) is formed as a concave spherical surface having a single radius (R) centered on the central axis (I) of the cavity (31).

3. A die according to claim 1 or claim 2, wherein, when the self-piercing rivet (10) is driven into the fastened members (41, 42), the legs (12) pierce the fastened member (41) on the punch side, the tips (13) of the legs (12) push downward through the fastened member (42) on the receiving side adjacent to the die (30; 35), the die (30; 35) receives the fastened member (42) on the receiving side deforming the tips (13) of the legs (12) so as to expand outward radially and remain inside the die (30; 35) without piercing the fastened member (42) on the receiving side adjacent to the die (30; 35), and the plurality of fastened members (41, 42) are fastened to each other by the head (11) and the expanded legs (12) of the self-piercing rivet (10).

4. A die according to any one of claims 1 through 3, wherein the upper surface of the die (30; 35) and the upper portion of the cavity (31; 36) are continuous at an obtuse angle.

5. A die according to any one of claims 1 through 4, wherein the depth (D) from the upper surface of the die (30; 35) to the central portion of the cavity (31; 36) is from 0.5 to 1.5 mm, particularly from 0.5 to 1.4 mm, preferably from 0.5 to 0.9 mm.

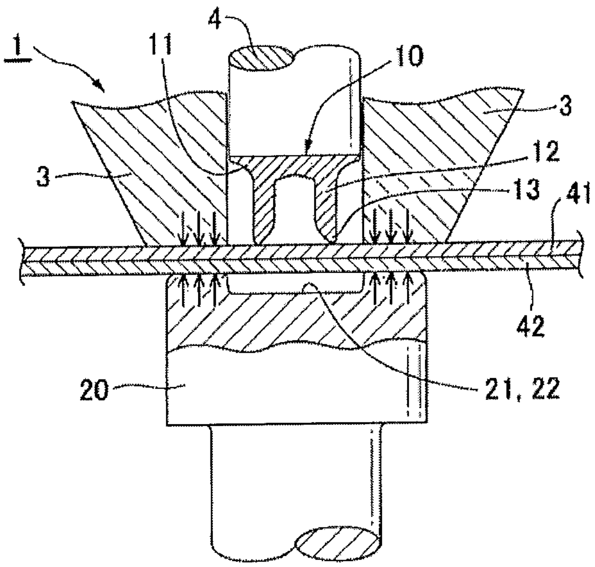
6. A die according to any one of claims 1 through 5, wherein the diameter (ϕ) of the cavity (31; 36) in the upper surface of the die (30; 35) is from 10 to 18 mm, particularly from 11 to 15 mm or from 13 to 18 mm.

7. A die according to any one of claims 1 or 3 through 6, wherein the round bottom surface is flat.

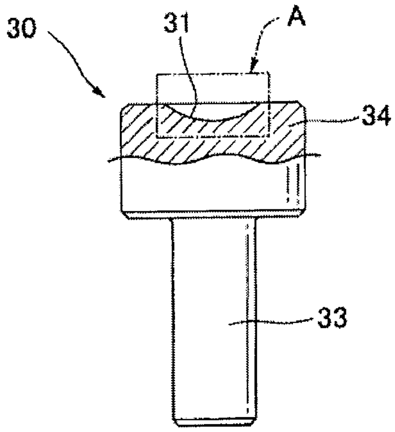
8. A die according to any one of claims 1 or 3 through 6, wherein the round bottom surface is a concave spherical surface.

9. A die according to any one of claims 2 to 8, wherein the radius of the concave spherical surface is in the range of 9 mm to 70 mm, particularly from 14 mm to 70 mm, and preferably from 20 mm to 60 mm.

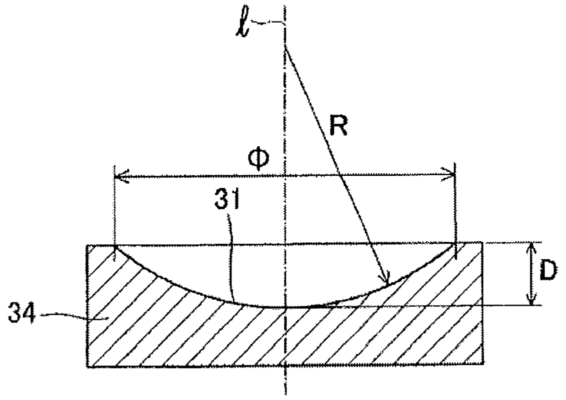
[FIG. 1]



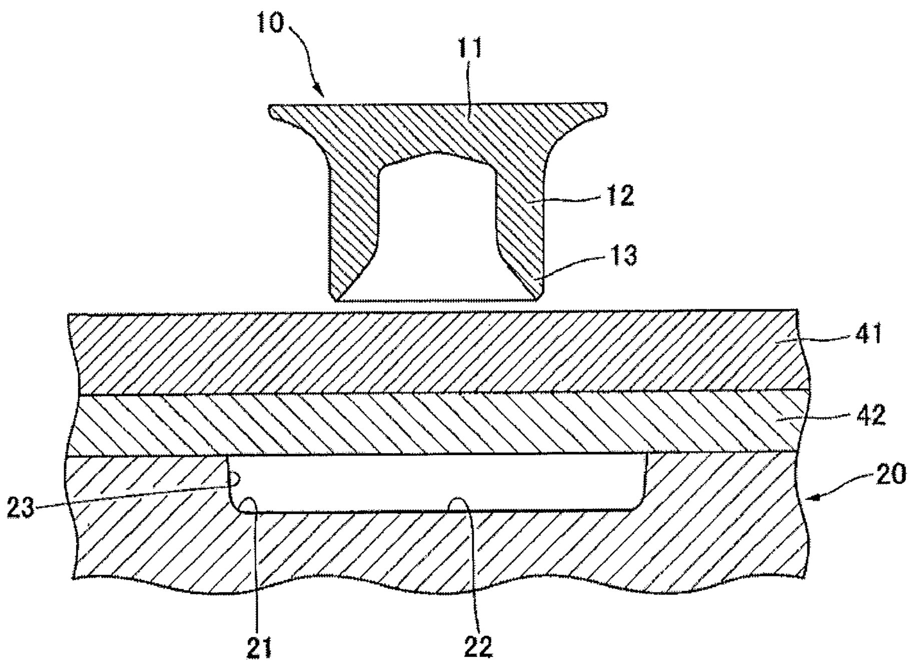
[FIG. 2]



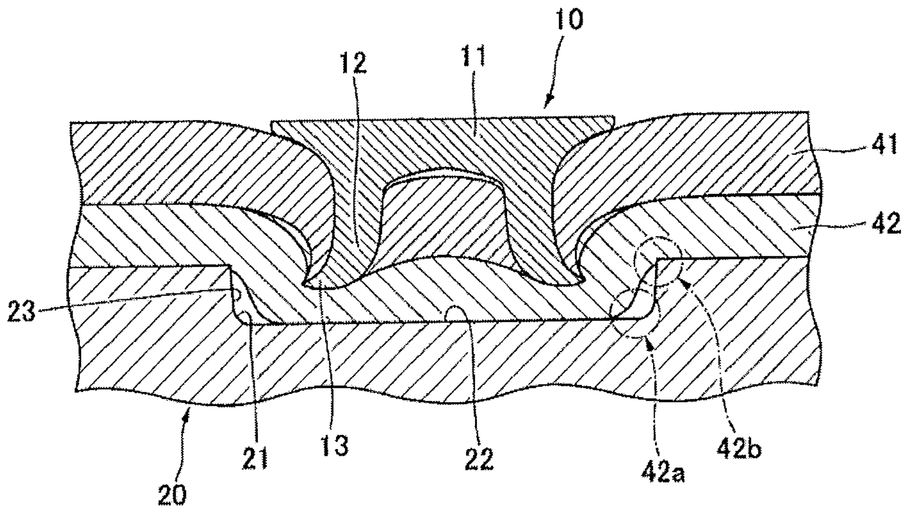
[FIG. 3]



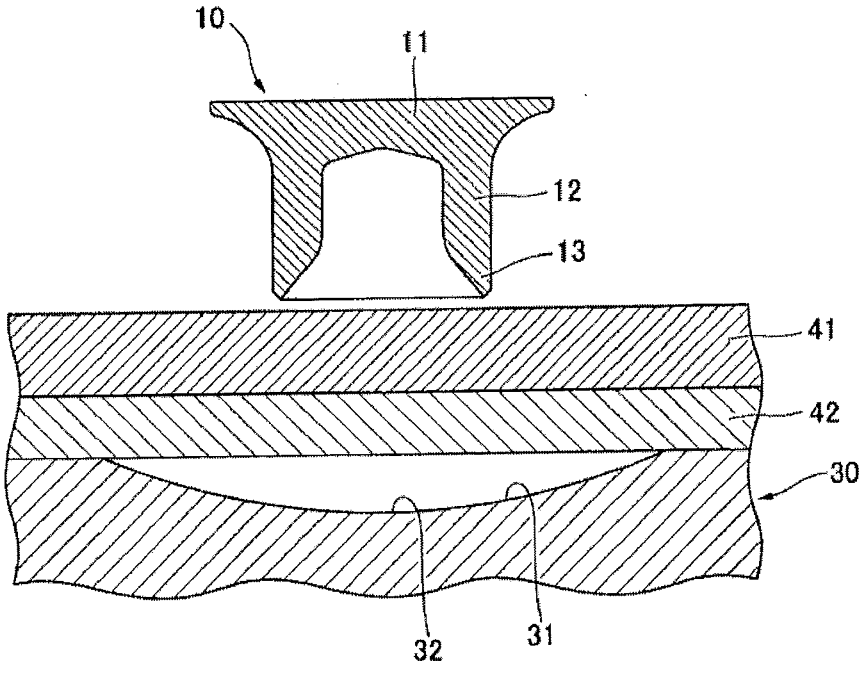
[FIG. 4A]



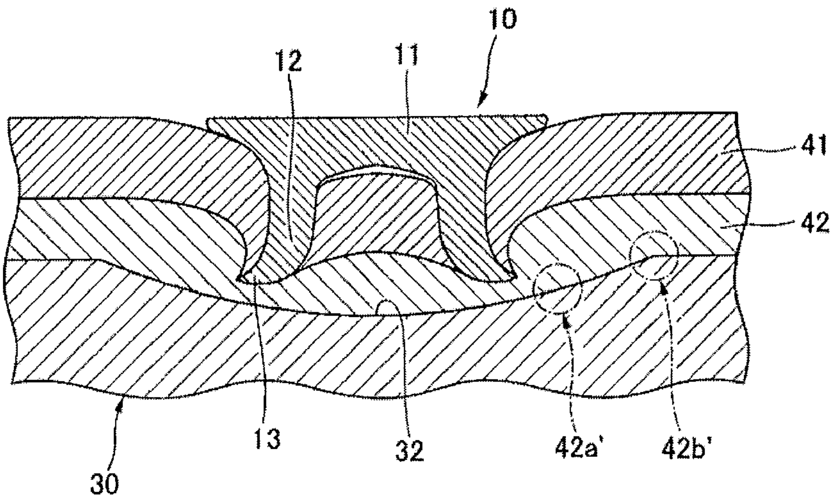
[FIG. 4B]



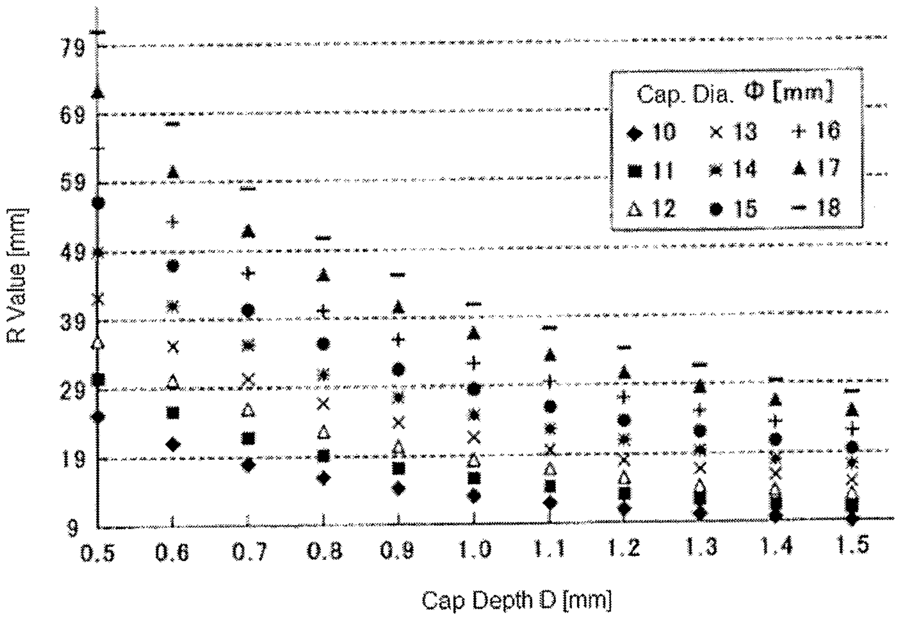
[FIG. 5A]



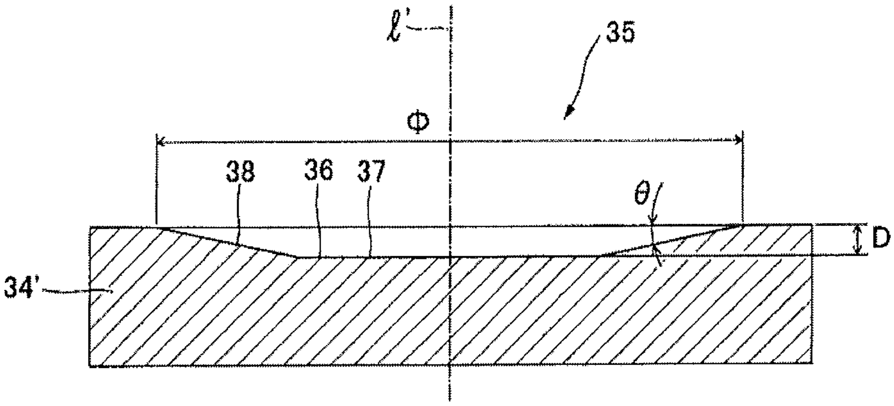
[FIG. 5B]


10
12
11
41
42
13
32
42a'
42b'
30

[FIG. 6]

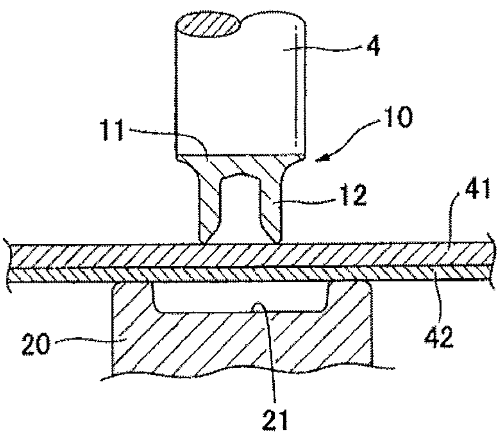

Cap. Dia. Φ [mm]
10
11
12
13
14
15
16
17
18
R Value [mm]
79
69
59
49
39
29
19
9
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
Cap Depth D [mm]

[FIG. 7]

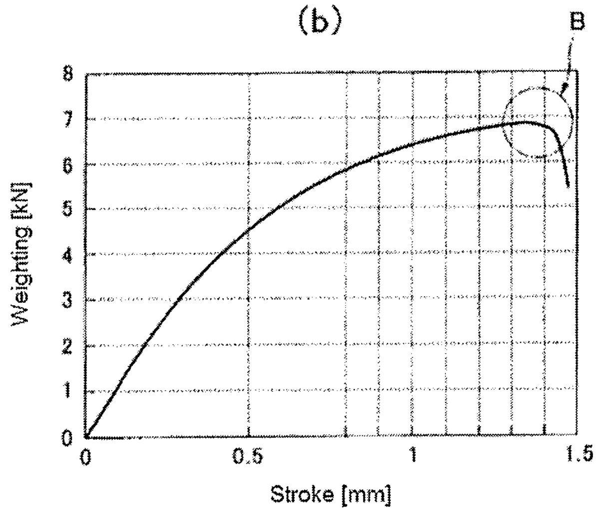

ℓ'
35
Φ
38
36
37
θ
D
34'

[FIG. 8]

(a)

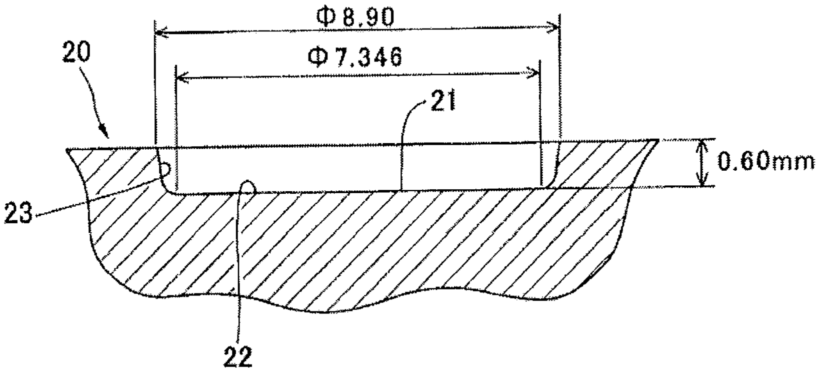

4
11
10
12
41
20
42
21

(b)

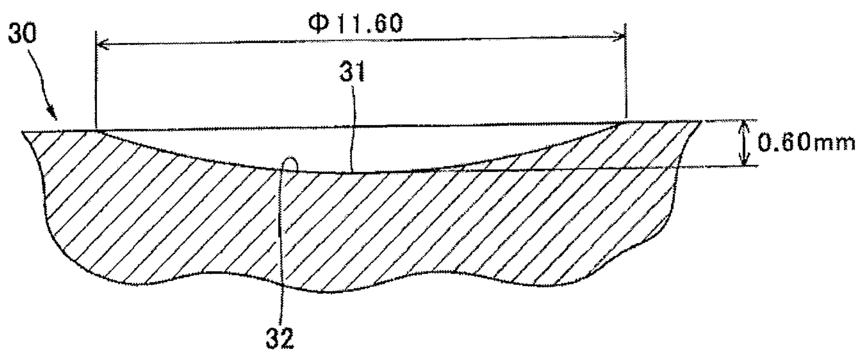

B
Weighting [kN]
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
Stroke [mm]

[FIG. 9]

(a)



(b)



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EUROPEAN SEARCH REPORT

Application Number
EP 12 19 8014

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	6 May 2013	Augé, Marc

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