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(72) Inventeurs/Inventors:
HILL, JOHN EDWARD, US;
DEVERS, TERENCE ANTHONY, CA

(73) Propriétaire/Owner:
MAGNA INTERNATIONAL INC., CA

(74) Agent: GOWLING WLG (CANADA) LLP

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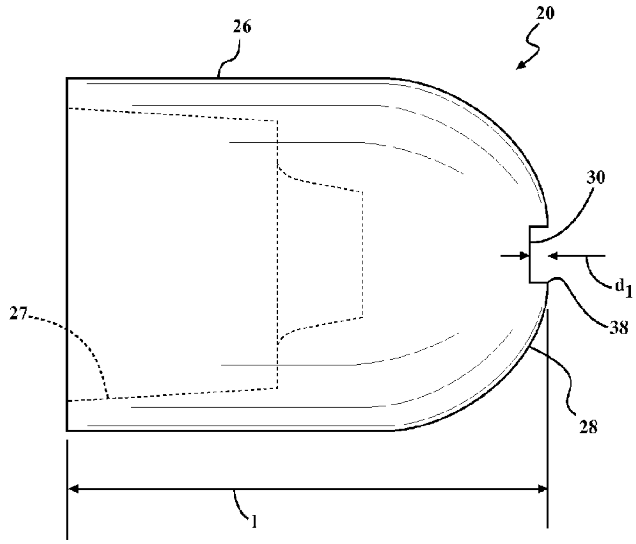

(57) Abrégé/Abstract:
A welding tip (20) for spot welding a first part (22) formed of conductive metal, for example aluminum, to a second part (24) formed of aluminum or another conductive metal, such as steel, is provided. The welding tip (20) includes a notch (30) at a distal end (38) and a convex contact surface (28) extending radially outwardly and upwardly from the notch (30) for engaging a surface of the first part (22). The rotating welding tip (20) forms a depression (32) on the surface of the first part (22) during the welding process. The notch (30) creates a pin (34) in the center of the depression (32) which provides a fixed axis of rotation for the rotating welding tip (20) and prevents the welding tip (20) from moving radially relative to the fixed axis, thereby improving the quality of the final spot weld (36) and reducing process time.

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(71) Applicant: **MAGNA INTERNATONAL INC.** [CA/CA]; 337 Magna Drive, Aurora, ON L4G 7K1 (CA).

(72) Inventors; and
(71) Applicants : **HILL, John, Edward** [CA/US]; 11662 Watkins Drive, Shelby Township, MI 48315 (US). **DEVERS, Terence, Anthony** [CA/US]; 1387 Kains Woods Terrace, London, ON N6K 4Z8 (CA).

(74) Agents: **SLAVEN, Kimberly M.** et al.; Dickinson Wright PLLC, 2600 West Big Beaver Road, Suite 300, Troy, MI 48084 (US).

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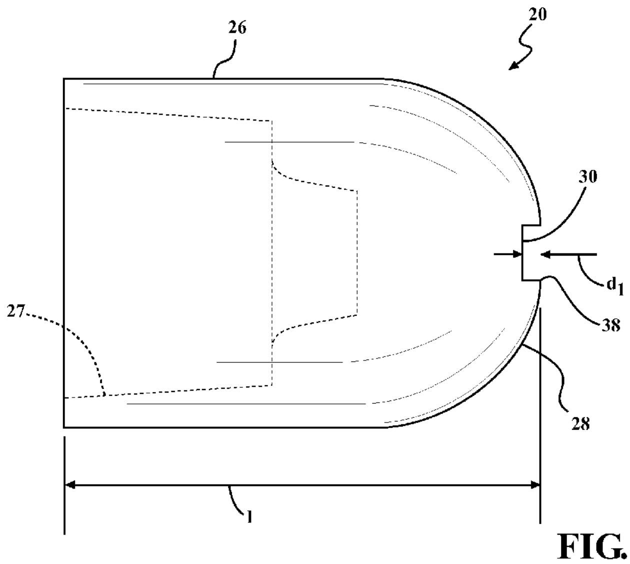

FIG. 1

(57) Abstract: A welding tip (20) for spot welding a first part (22) formed of conductive metal, for example aluminum, to a second part (24) formed of aluminum or another conductive metal, such as steel, is provided. The welding tip (20) includes a notch (30) at a distal end (38) and a convex contact surface (28) extending radially outwardly and upwardly from the notch (30) for engaging a surface of the first part (22). The rotating welding tip (20) forms a depression (32) on the surface of the first part (22) during the welding process. The notch (30) creates a pin (34) in the center of the depression (32) which provides a fixed axis of rotation for the rotating welding tip (20) and prevents the welding tip (20) from moving radially relative to the fixed axis, thereby improving the quality of the final spot weld (36) and reducing process time.

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ALUMINUM SPOT WELDING METHOD

[0001]

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The invention relates generally to spot welding methods, tools used for spot welding, and parts joined by spot welding.

2. Related Art

[0003] Spot welding is oftentimes used to join a first part formed of aluminum to a second part formed of aluminum or another metal material. The parts are held together under pressure by a pair of welding tips, which also function as electrodes. Current is supplied to the welding tips and concentrated in a single spot to melt the surface and form the weld. One drawback of spot welding aluminum parts is that aluminum oxides typically form along the surfaces, which reduces the integrity of the weld.

[0004] To break the oxide surface and reduce the amount of aluminum oxides formed during spot welding, the welding tips can present a spherical radius at their terminal end, and rotate continuously or intermittently at a controlled rate as they spot weld the parts together. An example of this technique was developed by KUKA and Mercedes-Benz® and is referred to as robo-spinning. The robo-spinning technique uses a robot to rotate the welding tips and spot weld the parts together. However, due to the significant force applied and the shape of the part being welded, the rotating weld tips tend to move out of position

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during the spot welding process. In addition, the terminal ends of the rotating welding tips can melt the surfaces of the parts and create locking divots.

SUMMARY OF THE INVENTION

[0005] The invention provides a welding tip for spot welding parts formed of conductive metal, such as aluminum. The welding tip comprises a shaft extending to a distal end and presenting a notch at the distal end. The shaft also includes a contact surface extending radially outwardly from the notch.

[0006] The invention also provides a method for spot welding. The method includes providing a first part formed of conductive metal and a second part formed of conductive metal. The method then includes contacting the first part with the welding tip while rotating the welding tip around its center axis.

[0007] The invention further provides a spot welded structure formed using the welding tip. The spot welded structure comprises the first part formed of conductive metal joined to the second part formed of conductive metal by a spot weld. The spot weld comprises a depression and a pin extending upwardly from the depression.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0009] Figure 1 is a side cross-sectional view of a welding tip according to an exemplary embodiment of the invention;

[0010] Figure 2 is a bottom view of the welding tip of Figure 1;

[0011] Figure 3 is a chart illustrating phases of a spot welding process according to an exemplary embodiment;

[0012] Figure 4 illustrates a pair of welding tips spot welding a first part to a second part according to an exemplary embodiment;

[0013] Figure 5 illustrates a structure including a first part spot welded to a second part according to an exemplary embodiment; and

[0014] Figure 6 shows the top and bottom of the spot welded structure of Figure 5.

DETAILED DESCRIPTION

[0015] The invention provides a welding tip **20**, as shown in Figures 1 and 2, for spot welding a first part **22** formed of conductive metal, typically aluminum, to a second part **24** formed of conductive metal, such as aluminum or another metal. The spot welding process is preferably a robo-spin or electromechanical motion spin process, for example the process illustrated in Figures 3 and 4, wherein the welding tip **20** rotates around its center axis **A** either continuously or intermittently. A high quality spot welded structure **25** including the first part **22** joined to the second part **24** by a spot weld **36**, such as the structure **25** shown in Figures 5 and 6, can be formed by the method of the present invention. The welding tip **20** and method of the present invention can also avoid forming divots along the surface of the parts **22**, **24**, which are often formed by traditional spot welding tips. The welding tip **20** can also reduce the total spot welding process time. More specifically, the time it takes to fix the rotating welding tip **20** to one of the parts **22**, **24** is reduced. In addition, the welding tip **20** requires less electrical current during the spot welding process, compared to a traditional welding tip.

[0016] The welding tip **20** may be formed of a copper alloy or another electrically conductive material so that when the welding tip **20** receives an electrical current the welding tip **20** functions as an electrode. The welding tip **20** of Figure 1 is uncoated, but the welding tip **20** may alternatively be coated to reduce friction while rotating around its center axis **A** and thus experience less wear.

[0017] The welding tip **20** includes a shaft **26** which is typically disposed in a spot welding gun (not shown). The shaft **26** extends along the center axis **A** to a distal end **38** and includes a notch **30** at the distal end **38**. A contact surface **28** surrounds the notch **30** at the distal end **38** for engaging the parts **22**, **24** to be welded. As shown in Figures 1 and 2, the contact surface **28** extends radially outwardly and upwardly from the notch **30**. The contact surface **28** also has a spherical radius which provides a rounded surface adjacent the distal end **38**. In the exemplary embodiment, the contact surface **28** presents a convex or semi-spherical shape. The area of the contact surface **28** and the size of the spherical radius can vary, depending on certain parameters, including, but not limited to, the thickness of the parts **22, 24** to be joined. Alternatively, other shapes may be used instead of the convex surface, depending on the desired formation of the spot weld **36** to be formed.

[0018] In the exemplary embodiment of Figure 1, the shaft **26** includes a slot **27** extending along the center axis **A** for receiving another component of the welding gun (not shown) which conveys the electrical current to the welding tip **20** during the welding process. The end of the slot **27** is spaced axially from the contact surface **28** of the spot welding tip **20**.

[0019] The notch **30** of the welding tip **20**, also referred to as a cavity, dimple, depression, or arbor, reduces the area of the surface in contact with one of the parts **22**, **24**. As a result of the reduced area, the welding tip **20** requires less electrical current during the spot welding process, compared to a traditional welding tip. The notch **30** is preferably located at an apex of the convex contact surface **28** and extends inwardly along the center axis **A** away from the distal end **38**, as shown in Figures 1 and 2. The cross-section of the notch **30** typically has a circular shape, as shown in Figure 2, but can comprise other shapes. The diameter $\mathbf{D_1}$ of the notch **30** can vary depending on the size of the contact surface **28** and the parts **22, 24** to be joined, or other factors. However, the cross-sectional area of the contact surface **28** surrounding the notch **30** is typically greater than the cross-sectional area of the notch **30**, as shown in Figure 2.

[0020] The depth $\mathbf{d_1}$ of the notch **30** can also vary depending on the size of the shaft **26** and parts **22, 24** to be joined, or other factors. In the exemplary embodiment of Figure 1, the depth $\mathbf{d_1}$ of the notch **30** is contained within the spherical portion of the welding tip **20** and is spaced from the slot **27** which receives the component of the welding gun. For example, the depth $\mathbf{d_1}$ of the notch **30** could be less than 30 percent (%), or less than 20 %, or less than 10 %, or less than 5 % of the distance between the distal end **38** of the welding tip **20** and the slot **27** for receiving the welding gun. The depth $\mathbf{d_1}$ of the notch **30** could also be less than 10 %, or less than 5 %, or less than 1 % of the total length **l** of the welding tip **20**.

[0021] During the spot welding process, the contact surface **28** of the rotating welding tip **20** forms a depression **32** on the surface of one of the parts **22, 24** to be joined. As the contact surface **28** forms the depression **32**, the notch **30** creates a pin **34** extending upwardly from the center of the depression **32**. The notch **30** fixes or secures the welding tip **20** to the surface of one of the parts **22, 24**, and the pin **34** provides a fixed axis of rotation for the welding tip **20**. The pin **34** also prevents the welding tip **20** from moving radially relative to the center axis **A** while rotating around the center axis **A**. The notch **30** also allows for precise location of applied force and electrical current which further prevents the rotating welding tip **20** from moving out of position. As alluded to above, the notched welding tip **20** has much higher electrode force density and requires less initial electrical current during the welding process -- compared to a traditional welding tip, since the contact surface **28** is reduced. The depression **32** and pin **34** remain on the final spot welded structure **25** as a witness to the process quality. It can be measured as a quality indicator relating to roundness in shape and surface indentation depth.

[0022] The invention also provides a method for joining the first part **22** formed of conductive metal to the second part **24** formed of conductive material by a spot welding method using the notched welding tip **20** and thus forming the spot welded structure **25**. The method preferably includes the robo-spinning technique, but can comprise another method that involves rotating the welding tip **20** around its center axis **A**, either continuously or intermittently. Figure 3 illustrates phases of an exemplary method used to spot weld the parts **22, 24**, including the degree of force **F**, electrical current **I**, and electrical resistance **R** applied during each phase of the spot welding process.

[0023] The method begins by providing the first part **22** and the second part **24** to be welded. The first part **22** is formed of conductive metal, such as aluminum, and the second part **24** is also formed of conductive metal, which is typically aluminum, but may be another conductive metal, such as steel. The size and shape of the parts **22, 24** can vary depending on the intended application of the finished spot welded structure **25**. For example, the parts **22, 24** can be designed for use as a component of an automotive vehicle. In addition, the parts **22, 24** can be pre-conditioned in any manner know in the art to improve the integrity of the spot weld **36** ultimately joining the parts **22, 24**. The conductive metal of the parts **22, 24** can also be coated or uncoated. Coating thicknesses are becoming increasingly thicker to cope with corrosion issues. Exemplary coatings include aluminum, zinc, and combinations of alloys to protect the conductive metal from corrosion.

[0024] Typically, the method employs two of the notched welding tips **20**, including the first welding tip **20** and a second welding tip **20'**, as shown in Figure 4. A pair of welding guns (not shown) each including one of the notched welding tips **20, 20'** are used to spot weld **36** the parts **22, 24**. As shown in Figure 4, the first and second welding tips **20, 20'** are aligned on opposite sides of the parts **22, 24** to be joined. The welding tips **20, 20'** preferably have the same design and perform the same function at the same time. For example, the first welding tip **20** engages the first part **22** while the second welding tip **20'** engages the second part **24**, or vice versa. Accordingly, although the following description refers to only the first welding tip **20** and the first part **22** in several instances, the description also applies to the second welding tip **20'** and the second part **24**.

[0025] The method begins with a first phase including supplying power to the welding gun, which drives the welding tip **20** to rotate around its center axis **A**, preferably before contacting the part **22**. In the exemplary embodiment, the rotating step begins before the welding tip **20** contacts the surface of the part **22** in order to reduce process time. The first phase of the exemplary spot welding process also includes crimping the parts **22, 24** before any electrical current **I** or heat is applied to the welding tips **20, 20'** or the parts **22, 24**. This cold crimping first phase can be applied in any situation, but is typically applied when a gap between the parts **22, 24** is present, for example, due to manufacturing tolerances. The first phase comprises a first period of time at the start of the welding process, during which the rotating welding tips **20, 20'** first contact a spot along the surface of each of the parts **22, 24**. As shown in Figure 3, no electrical current **I** is applied to the welding tips **20, 20'** during the first phase. Once the rotating welding tips **20, 20'** contact the parts **22**, **24**, the first phase includes applying a significant force **F** to the parts **22**, **24** by the welding tips **20, 20'**. The center axis **A** of the first welding tip **20** is aligned with the center axis **A'** of the second welding tip **20'**, as shown in Figure 4, as the welding tips **20, 20'** rotate.

[0026] The welding tip **20** can rotate continuously or intermittently during the first phase. As the rotating welding tip **20** develops force, any oxide layer present on the surface of the part **22** is removed. The rotating welding tip **20** can also score, remove, condition, or scrub any coating on the surface of the part **22**. At the end of the first phase, the force **F** applied to the welding tip **20** is typically reduced in preparation for the second phase.

[0027] The second phase of the exemplary method shown in Figure 3 includes softening the part **22**. During the second phase, which is a second period of time immediately following the first period of time, the force **F** is still applied to the rotating welding tip **20** at a constant level. The electrical current **I** is then turned on and applied to the welding tip **20** in order to soften the part **22**. Figure 3 shows that the electrical current **I** initially increases and then stays at a constant level throughout the second phase, while the electrical resistance **R** is highest at the beginning of the second phase and decreases continuously throughout the second phase.

[0028] The temperature of the part **22** also increases during the second phase as the welding tip **20** continues to rotate while in contact with the part **22**. Thus, the spot along the surface of the part **22** engaged by the rotating welding tip **20** begins to melt, and the welding tip **20** begins forming the depression **32** and the pin **34** extending upwardly from the center of the depression **32**. Once the pin **34** forms, the welding tip **20** rotates about the pin **34**. The notch **30** and pin **34** fix the axis of rotation at the center axis **A** of the welding tip **20** and prevent the welding tip **20** from moving radially relative to the center axis **A** during the rotating step. In other words, the notch **30** and pin **34** fix or secure the welding tip **20** to the part **22** and prevent the welding tip **20** from moving or shifting radially relative to its center axis **A** during the rotating step of the second phase.

[0029] The welding tip **20** can rotate continuously or intermittently during the second phase. In either case, the welding tip **20** rotates quickly enough to prevent the melted aluminum or other conductive metal of the part **22** from sticking to the contact surface **28** or notch **30** of the welding tip **20**. The lack of oxides on the surface of the part

22 also prevents the melted metal from sticking. Thus, the service life of the welding tip **22** is improved.

[0030] The third phase of the exemplary method shown in Figure 3 is the welding phase. During the third phase, which is a third period of time immediately following the second period of time, the force **F** is maintained at the same level as in the second softening phase. However, the electrical current **I** increases sharply to its highest level and stays at that level during the majority of the third phase, while the electrical resistance **R** continues to slowly decrease. As the welding tip **20** continues rotating, the temperature continues to increase and the spot along the surface of the part **22** continues to melt. During the third phase, the notch **30** continues to fix the welding tip **20** to the surface of the part **22**, while the pin **34** provides the fixed center axis **A** of rotation for the rotating welding tip **20**. Thus, the notch **30** allows for precise location of the applied force **F** and electrical current **I**, which leads to a higher quality spot weld **36** in the finished structure **25**. The notch **30** also continues to prevent the welding tip **20** from moving, sliding, or skidding out of position. Towards the end of the third phase, the spot weld **36**, also referred to as a weld nugget is typically formed between the two parts **22**, **24**. At the end of the third phase, the electrical current **I** is sharply reduced to zero, the electrical resistance **R** is gradually reduced to zero, and the temperature of the welding tip **20** and the part **22** begins to decrease. Thus, the part **22** begins to cool at the end of the third phase and after the third phase.

[0031] In the exemplary embodiment shown in Figure 3, the fourth phase includes forging. The forging is beneficial to reduce cracking along the surface of the part **22**, especially when the part **22** is formed of an alloy, but the forging step is not required. During the optional fourth phase, which is a fourth period of time immediately following the third period of time, the electrical current **I** is turned off, and the welding tip **20** and part **22** continue to cool. The force **F** applied to the part **22** by the welding tip **20** during the fourth phase increases relative to the second and third phases. The force **F** applied during the fourth phase is approximately equal to, or at least equal to the force **F** applied during the first phase, and the force **F** remains at this high level for a majority of the fourth phase. A high capacity welding gun may be required to achieve this high level of force **F** during the first and fourth phases. In addition, the welding tip **20** can optionally rotate during the fourth phase.

[0032] The welding tip **20** typically stops rotating continuously around its center axis **A** at some point after the third phase. If the method includes the optional fourth phase, then the welding tip **20** stops rotating continuously before, during, or after the fourth phase. A cooling phase (not shown in Figure 3) then begins either after the third phase or after the optional fourth phase, wherein the depressions **32** and pin **30** formed by the welding tip **20** can solidify and provide the finished spot weld **36** joining the first part **22** and the second part **24**. At beginning of the cooling phase, the welding tip **20** is still in contact with the part **22**, and the method preferably includes "swiveling" or rotating the welding tip **20** less than 360 degrees around its center axis **A** in a first direction, and preferably followed by rotating the welding tip **20** less than 360 degrees around its center axis **A** in a second direction opposite the first direction. For example, the swiveling step can include rotating 10 degrees in one direction, or rotating 5 degrees clockwise followed by 5 degrees counterclockwise. This swiveling step further prevents the aluminum or other conductive metal from sticking to the welding tip **20**. The swiveling motion can be repeated a plurality of times, either continuously or intermittently. The swiveling step can also be incorporated into other phases of the spot welding process. The pin **34** formed on the surface of the part **22** remains disposed in the notch **30** of the welding tip **20** during the swiveling step and keeps the welding tip **20** in position during the swiveling step.

[0033] The invention further provides a structure **25** including the first part **22** formed of aluminum and the second part **24** formed of aluminum or another metal material joined together by the spot weld **36**, as shown in Figures 5 and 6. The spot weld **36** comprises the depression **32** on the surface of each part **22, 24**, and the pin **34** extending upwardly from the center of each depression **32**. The depression **32** typically presents a concave surface and the pin **34** extends upwardly from the center of the concave surface. The pin **34** formed in the first part **22** is preferably aligned with the pin **34** formed in the second part **24**. The pin **34** makes it easy to identify spot welded structures **25** formed using the notched welding tip **20** of the present invention. The depth $\mathbf{d_2}$ and diameter $\mathbf{D_2}$ of each depression **32** can vary, depending on the size of the welding tip **20** and the pressures and temperatures of the spot welding process. However, the total cross-sectional area of each depression **32** is typically greater than the total cross-sectional area of each pin **34**, as shown in Figure 5. The spot weld **36** formed using the notched welding tip **20** is higher quality than spot welds formed using other welding tips without the notch **30**.

[0034] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the claims.

CLAIMS

1. A method for spot welding parts formed of conductive metal, comprising the steps of:

providing a first part formed of conductive metal and a second part formed of conductive metal;

contacting the first part with a first welding tip while rotating the first welding tip around a center axis of the first welding tip, the first welding tip including a shaft extending to a distal end and presenting a notch at the distal end, and the shaft including a contact surface extending radially outwardly from the notch;

applying no current to the first welding tip for a first period of time;

rotating the first welding tip before contacting the first part with the first welding tip during the first period of time; and

applying force to the first part by the first welding tip during the first period of time.

contacting a spot on the first part during the first period of time and during a second period of time immediately following the first period of time;

applying electrical current to the first welding tip during the second period of time;

melting the first part in the spot during the second period of time;

decreasing the force applied to the first part by the first welding tip during the second period of time;

contacting the spot on the first part during a third period of time immediately following the second period of time;

increasing the electrical current applied to the first welding tip while rotating the first welding tip during the third period of time;

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the rotating steps including continuously or intermittently rotating the first welding tip around the center axis of the first welding tip and forming a depression in the first part and a pin extending upwardly from the depression;

rotating the first welding tip about the pin, wherein the pin locks the first welding tip to the first part and prevents the first welding tip from moving radially relative to the center axis of the first welding tip during the rotating step; and

providing no electrical current to the first welding tip while increasing the force applied to the first part by the first welding tip and optionally rotating the first welding tip during a fourth period of time immediately following the third period of time.

2. The method of claim 1, wherein a cross-sectional area of said contact surface is greater than a cross-sectional area of said notch.

3. The method of claim 1, wherein said notch is located at an apex of said convex contact surface.

4. The method of claim 1, wherein said shaft is formed of conductive metal.

5. The method of claim 1, wherein the notch and the pin fix an axis of rotation of the first welding tip during the rotating step so that the center axis is the axis of rotation, and the notch and the pin prevent the first welding tip from moving radially relative to the fixed axis of rotation during the rotating step.

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6. The method of claim 1, wherein at least one of the first part and the second part is formed of aluminum or an aluminum alloy.

7. The method of claim 1 including allowing the first part to cool while still contacting the first part with the first welding tip after the third period of time by applying no electrical current to the first welding tip; and

rotating the first welding tip less than 360 degrees around the center axis of the first welding tip in a first direction and rotating the first welding tip less than 360 degrees around the center axis of the first welding tip in a second direction opposite the first direction while allowing the first part to cool and while contacting the first part with the first welding tip.

8. A method for spot welding parts formed of conductive metal, comprising the steps of:

providing a first part formed of conductive metal and a second part formed of conductive metal;

contacting the first part with a first welding tip while rotating the first welding tip around a center axis of the first welding tip, the first welding tip including a shaft extending to a distal end and presenting a notch at said distal end, and the shaft including contact surface extending radially outwardly from the notch;

contacting the second part with a second welding tip while contacting the first part with the first welding tip;

rotating the second welding tip around a center axis of the second welding tip while rotating the first welding tip around the center axis of the first welding tip, the second welding tip

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including a shaft extending to a distal end and presenting a contact surface around the distal end, and the shaft presenting a notch at the distal end;

applying no current to the second welding tip for a first period of time;

rotating the second welding tip before contacting the second part with the second welding tip during the first period of time; and

applying force to the second part by the second welding tip during the first period of time.

9. The method of claim 8, wherein a cross-sectional area of the contact surface of the first welding tip extends upwardly from the notch to the perimeter surface, and the notch is located at an apex of the contact surface.

10. The method of claim 8, wherein the center axis of the first welding tip is aligned with the center axis of the second welding tip during the step of rotating the second welding tip around the center axis of the second welding tip while rotating the first welding tip around the center axis of the first welding tip.

Date Reçue/Date Received 2020-07-13

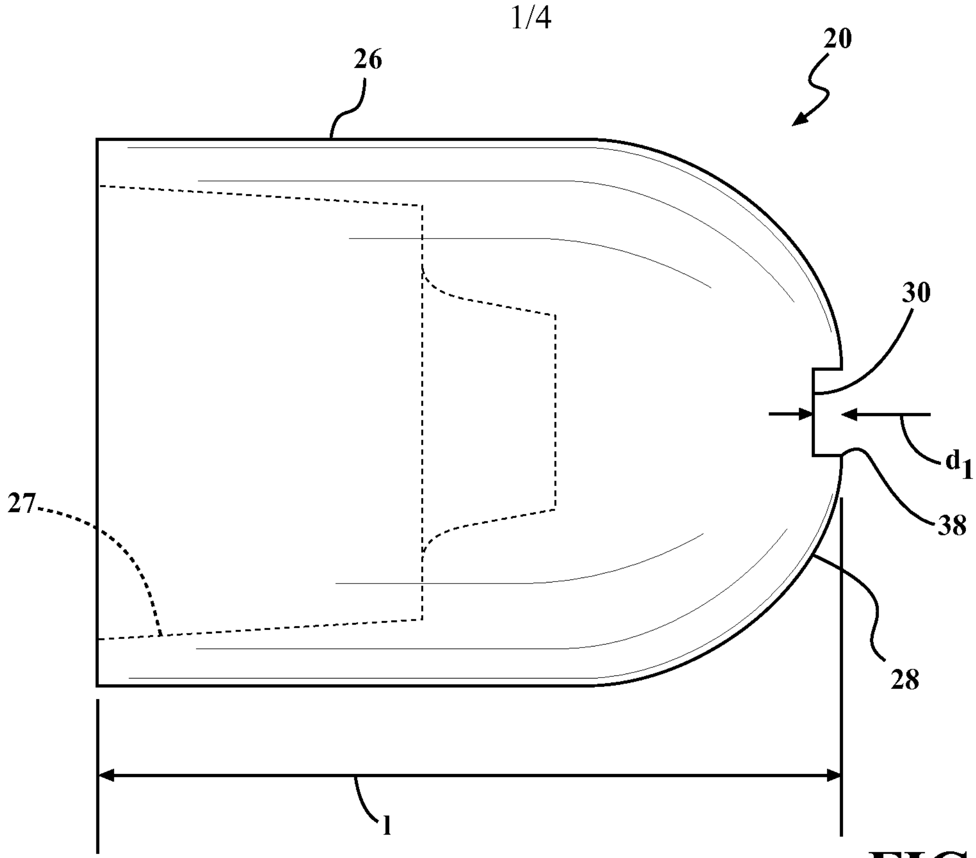


FIG. 1

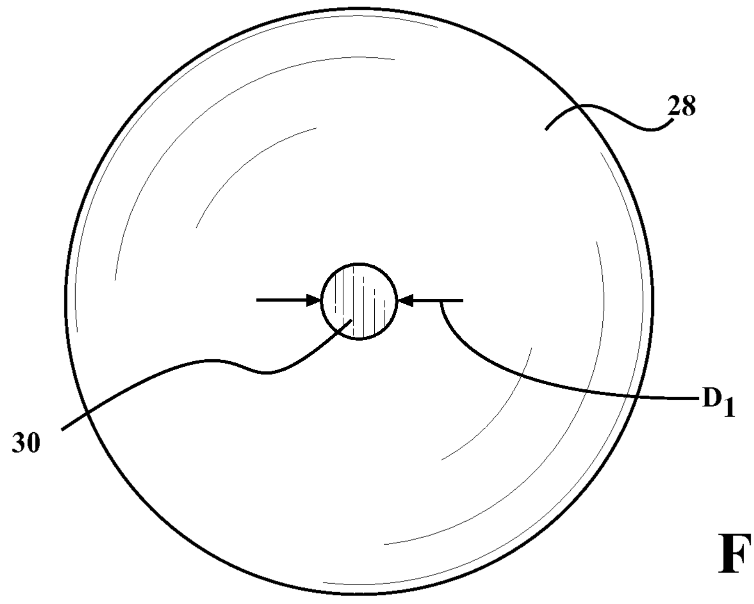
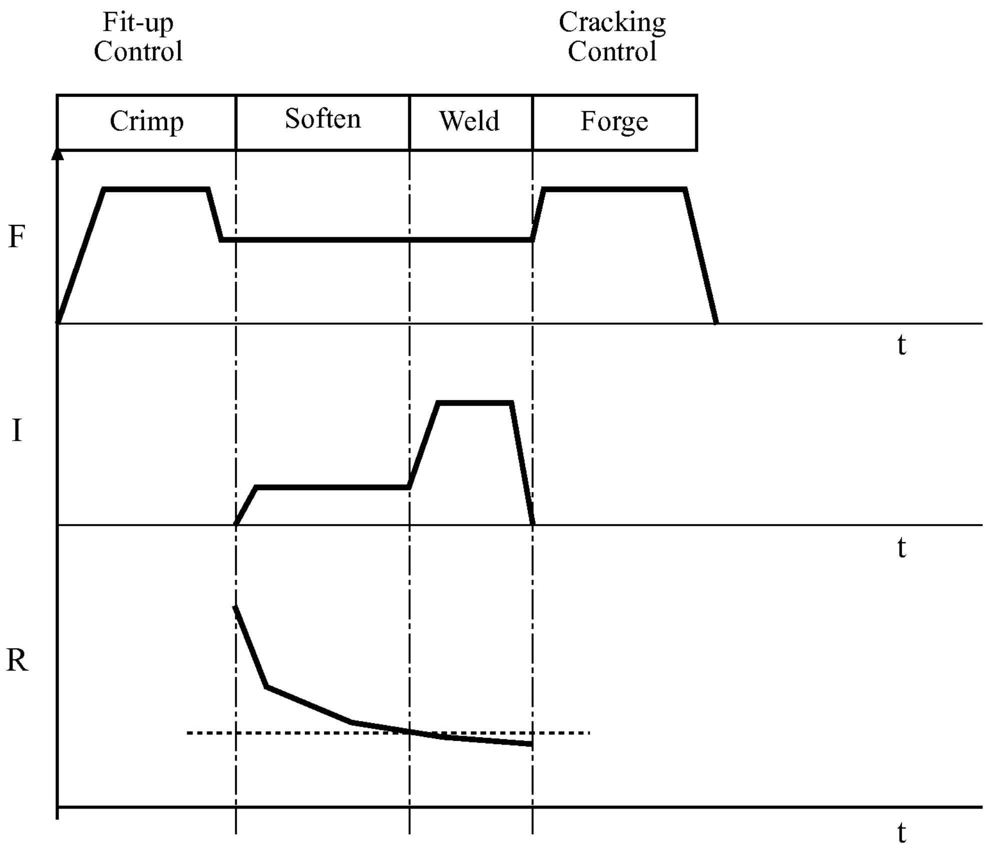


FIG. 2


Fit-up
Control
Cracking
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Crimp
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FIG. 3

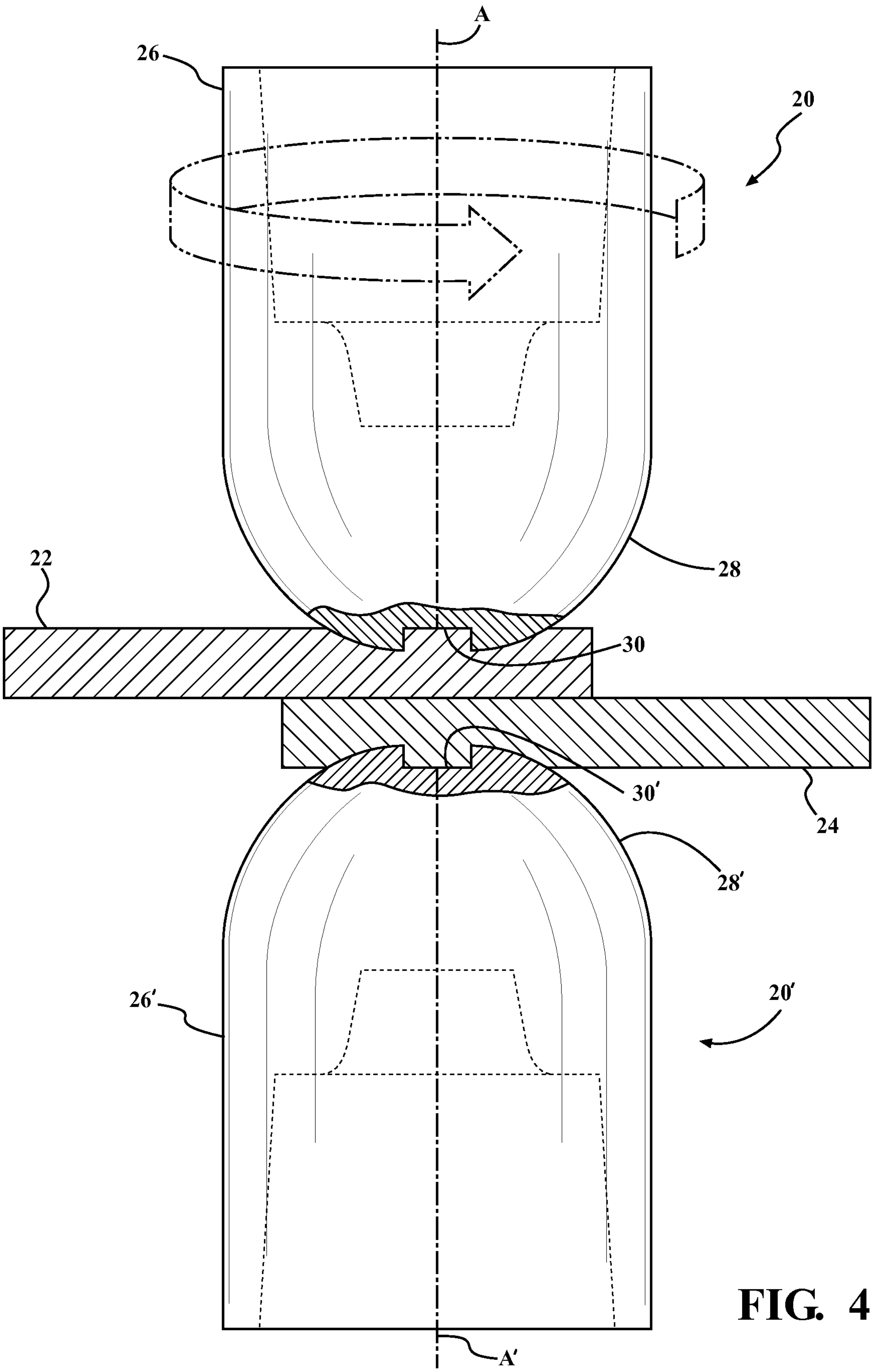


FIG. 4

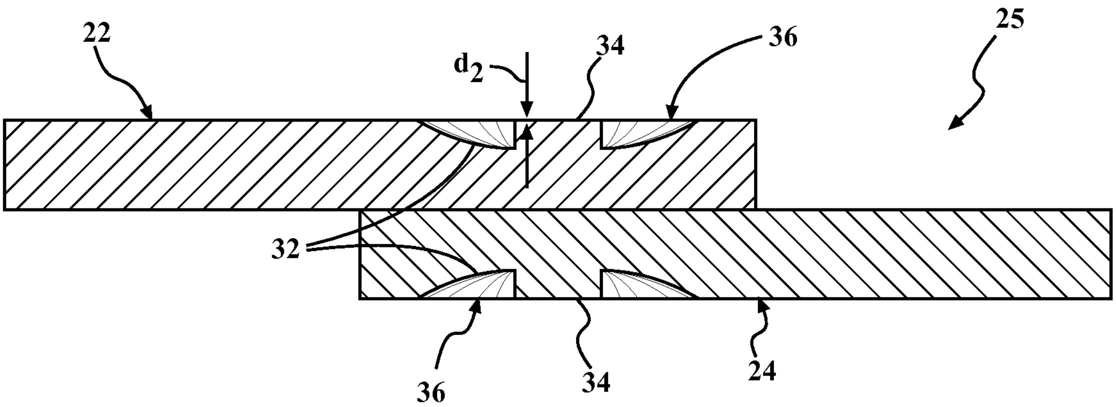


FIG. 5

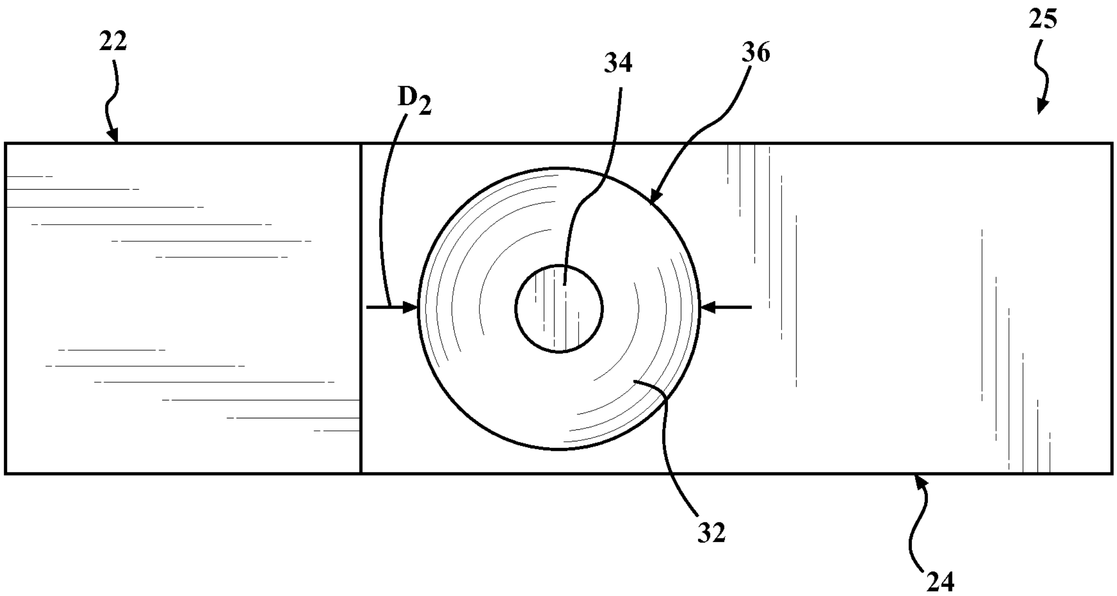
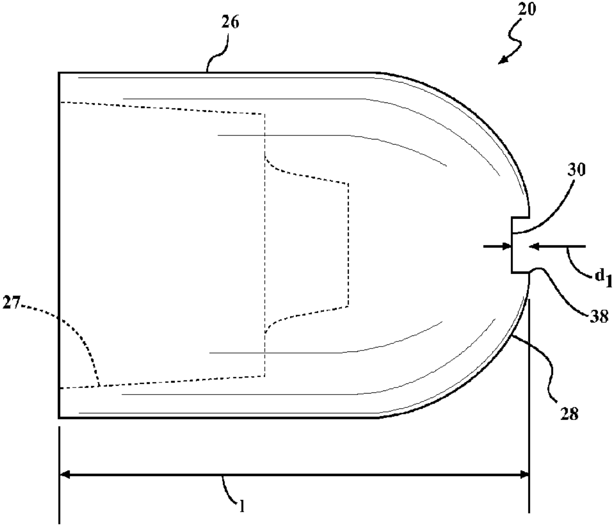


FIG. 6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