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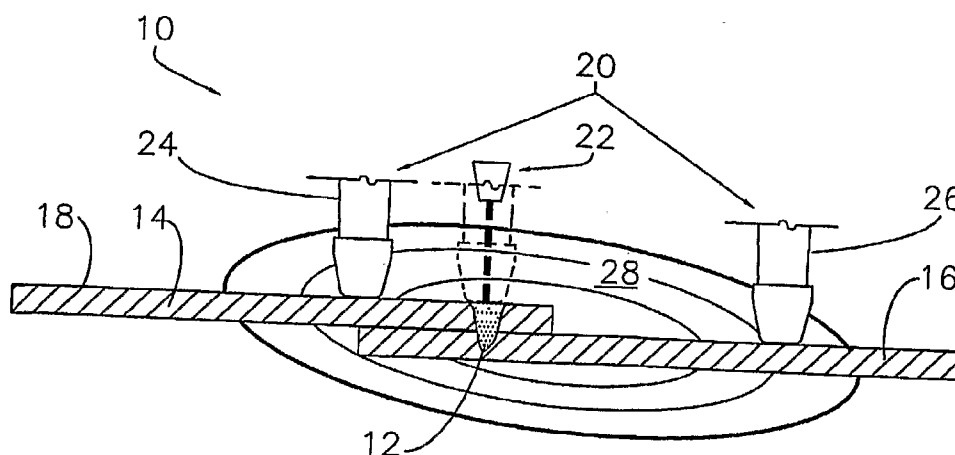
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(54) Title: HYBRID LASER AND RESISTANCE WELDING SYSTEM AND METHOD



(57) Abstract: An improved fusion welding system having a heating unit and welding device is adapted for increasing the efficiency of welding a plurality of workpieces. The system preferably presents a single-sided process, and includes first and second electrode wheels operable to heat a portion of the workpieces to a minimum temperature, and a translatable laser cooperatively configured to form a continuous weld within the heated portion. The preferred system provides the advantages of laser welding, such as precision, while enabling weld production at lower laser power outputs or faster welding speeds than conventional laser welding systems.

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HYBRID LASER AND RESISTANCE WELDING SYSTEM AND METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to welding systems, and more particularly to a fusion welding system including a heating unit and welding device for combination heating and welding.

2. Discussion of Prior Art

[0002] The process of material joining and treatment is a necessary condition for the industrial progress. As such, fusion-welding systems have been developed for joining multi-component workpieces. One such system, laser spot and seam welding utilizes laser heat energy during joining, and is commonly used, for example, in the automotive industry.

[0003] These conventional systems are typically used to provide faster welding speeds and produce more accurate and precise welds than do counterpart resistance welding technologies. The power associated with the laser, and the material composition and initial state of the workpieces are directly proportional to the aspect ratio of weld depth to width. In other words, the more powerful the laser and focused the beam, the greater the heat energy density. However, while these benefits help minimize stresses experienced by the workpieces, they present other concerns. For example, these systems are typically limited by strict requirements of tolerance, porosity formation, poor gap bridgeability and hot cracking in the weld. Of further concern are the relative high costs associated with high-powered lasers (i.e., lasers having a power output greater than 4 kW), which are not solely a result of increased input energy demands.

[0004] These systems may also present construction concerns, where a high-powered laser is utilized to produce the fusion weld. The rapid change in temperature from initial room temperatures to temperatures greater than the melting range of the material, coupled with the speed of weld formation contribute to the production of pores formed by trapped gas, and cracking within the relatively narrow weld. The formation of pores and cracking further reduces the structural integrity of the weld.

[0005] Other welding systems, such as conventional hybrid laser-arc systems that feature the simultaneous application of heat generated from laser radiation and an electric arc,

require high powered laser output for, and therefore, experience the same concerns during combination welding.

[0006] Thus, there is need in the art for an improved laser welding system that minimizes costs and the likelihood of construction inefficiencies that arise from high powered laser welding.

BRIEF SUMMARY OF THE INVENTION

[0007] Responsive to these and other concerns caused by conventional laser welding systems, the present invention provides an improved system for decreasing the costs and structural inefficiencies associated therewith. This invention provides a method of welding workpieces using multiple sources for in tandem pre-heating and welding. The invention is further useful, among other things, for substantially pre-heating the workpieces with a heating unit, to increase the applicability of low-powered laser welding.

[0008] More particularly, a first aspect of the present invention concerns a system for welding a plurality of workpieces. The system preferably comprises first and second electrode wheels, and a laser configured to engage and further heat a first portion. The wheels are preferably configured to cooperatively pre-heat the first portion of the workpieces to a temperature at least equal to a predetermined percentage of the melting range of the first portion. The wheels and laser are preferably translatable relative to the workpieces, and cooperatively configured to form a continuous weld between the plurality of workpieces.

[0009] A second aspect of the present invention concerns a method of increasing the efficiency of laser-welding a plurality of workpieces. The method preferably comprises the steps of pre-heating a portion of the workpieces to a minimum temperature using a heating unit, further heating the portion with a laser beam until the first portion melts, and cooling the portion to a temperature less than the melting range, so as to allow the portion to re-solidify and form a weld.

[0010] Other aspects and advantages of the present invention will be apparent from the following detailed description of the preferred embodiment(s) and the accompanying drawing figures.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0011] A preferred embodiment of the invention is described in detail below with reference to the attached drawing figures, wherein:

configuration and a welding system in accordance with a preferred embodiment of the present invention, particularly illustrating a spot welding system;

FIG. 2 is a perspective view of a plurality of workpieces in overlap configuration and a welding system in accordance with a preferred embodiment of the present invention, particularly illustrating a translatable system;

FIG. 3 is top view of the workpieces and a translatable system in accordance with a preferred embodiment of the present invention; and

FIG. 4 is a cross-sectional view of the workpieces and system shown in FIG. 3 taken along line A-A.

DETAILED DESCRIPTION OF THE INVENTION

[0012] The present invention concerns an improved fusion welding system 10 for welding a plurality (i.e., two or more) of overlapping adjacent workpieces, such as automotive sheet metal and engine cradle parts, to produce a weld 12. In the illustrated embodiments shown in FIGS. 1 through 4, a plurality of two workpieces 14,16 of equal thickness are shown; however, the system 10 may be utilized to weld a greater plurality or structural components having variable thickness. The workpieces may be formed of a wide range of materials including iron alloys, aluminum alloys, magnesium alloys, titanium and molybdenum. As shown in FIG. 1, the positioned workpieces 14,16 present at least one outermost surface 18 that defines in part an outer edge and is exposed to the system 10. To facilitate accessibility, the system 10 preferably presents a single-sided process, in that it engages the workpieces 14,16 along surface 18 only. In this configuration, the workpieces 14,16 are supported on the opposite side by a backing plate or clamping fixture (not shown). Although described herein with respect to workpieces, it is well within the ambit of the present invention for the system 10 to be used in other ways, wherein repair or welding is desired, such as patching an existing structure.

[0013] Turning to the configuration of the system 10, a heating unit 20 is provided for heating a portion of the workpieces 14,16 so as to increase the temperature of the portion to a minimum temperature. A welding device 22 is operable to further heat of the portion past the melting range of the portion. The unit 20 and device 22 may be manually controlled, or controlled by electro-mechanical means (not shown). More preferably, the system 10 is robotically controlled along multi-axes and is programmably adjustable.

of electrodes 24,26 configured to pass an electric current (not shown) through the portion of the workpieces. The resistivity of the workpieces 24,26 produces radiant and conductive heat energy, and creates a heat-affected-zone (HAZ) 28 that encompasses the soon to be welded portion (see, FIG. 1). It is appreciated by those ordinarily skilled in the art that total resistance is directly proportional to the linear distance between electrodes, and as such, resistance and therefore current flow can be varied by relocating the electrodes. The “pre-heated” portion extends through each workpiece, wherein weld nugget formation is desired (see, FIG. 1).

[0015] More particularly, electrodes 24,26 present an electric elevation, so as to produce a potential difference therebetween. For example, the power charged to electrode 24 may be approximately equal to 25 to 100 kVA, as is typically used for spot welding, while electrode 26 is grounded. The heating unit is preferably configured to produce a quantity of heat energy sufficient to heat the portion to a temperature not less than 10%, and more preferably not less than 20% of the melting range for steel or iron alloys, and not less than 30%, and more preferably 50% for aluminum alloys. It is further appreciated that workpieces 14,16 are significantly plasticized at these temperatures, thereby resulting in increased workability and thermal receptivity. Finally, the preferred electrodes 24,26 may be any suitable spot welding electrode, conductive connections, or similar devices, and the current may be a pulsed, alternating or direct current.

[0016] As further shown in FIGS. 1 through 4, the preferred device 22 includes a laser 30 operable to engage the outer surface 18 with a laser beam 30a having appropriate power to further heat the portion to a temperature greater than the melting range. As an intended benefit of pre-heating the portion, the laser 30 need not produce a high power output to form the weld 12. As such, a low power laser, i.e. maximum 4 kW, can be utilized for most sheet welding applications of the present invention. The sequence of operations, however, presents a parameter of functionality as the rate of cooling of the pre-heated workpieces 14,16 is directly related to the thermal conductivity of the workpiece material. Thus, so that the focused energy of the laser beam 30a could produce the weld pool by fusion, it must be applied within a maximum period from pre-heating, i.e. 5 s. Where welding is desired at the workpiece 14 – electrode 24 interface, the electrode must be removed (as shown by hidden line in FIG. 1) and the laser put in place within this period. After the laser beam 30a is applied, the weld pool is cooled by the surrounding material and atmosphere to solidify and form the weld 12.

welding systems, can be utilized to form the weld 12, it is appreciated by those ordinarily skilled in the art that the laser beam 30a provides one of the most accurate and consistent conventional means for welding. It is also appreciated that the relative cost of high powered laser welding realizes greater cost benefits of pre-heating, when compared to other welding devices 22. Finally, the application of resistance preheat prior to laser welding is further useful for significantly increasing the static strength of the joint. For example, the application of resistance preheat to 1.3 mm thick mild steel and 1.4 mm thick aluminum (AA5754) workpieces prior to laser welding utilizing either a CO₂ or Yag laser results in an increase in static strength approximately equal to 1,500 N and 2,500 N, or 15% and 100%, respectively.

[0018] More preferably, and as shown in FIGS. 2 through 4, the welding system 10 is also translatable with respect to the workpieces 14,16, so as to be capable of producing a continuous or seam weld. In this configuration, the system 10 preferably includes electrode wheels 32,34 that rollingly engage upper and lower workpieces 14,16. Among other factors, wheel placement relative to the laser 30 depends upon the application, available power, and workpiece geometry. A suitable copper alloy wheel electrode, as is typically used in seam welding, may be utilized in this configuration.

[0019] Since this is a single-sided process, to sustain the wheel pressure the lower sheet 16 should be equal to or thicker than the upper sheet. It is preferable that the thickness of the upper sheet 14 be less than 3 mm. For example, for upper sheets 14 of thicknesses less than 3 mm, the electrode wheels 32,34 may present roller widths less than or equal to 14 mm, with a supplied power output of 80 kVA (DC). The first wheel 34 may be spaced from the projected weld a distance, S_1 , within the range of 15 to 50 mm and made to contact the lower worksheet 16. Similar to the alternative electrode 24 locations shown in FIG. 1, the second wheel 32 may precede the laser 30 while contacting the upper workpiece 14 (as shown in FIG. 2, and by hidden line in FIG. 4), or be spaced from the longitudinal center line of the weld a distance, S_2 , not greater than 5 mm (as shown in FIGS. 3 and 4). It is appreciated that workpiece temperatures at the non-exposed wheel-workpiece interface present maximum initial temperatures for in tandem welding. However, where laser welding is performed intermediate the wheels, the laser beam 30a is absorbed more efficiently by the workpieces 14,16 and generally intercepts the current, thereby resulting in concurrent heating and welding.

[0020] A suitable laser 30 to be used in the present invention may include YAG lasers. It is appreciated that these lasers are flexible for beam delivery. It is further

utilized, in combination with the heating unit pursuant to the present invention, to weld materials 0.8 mm (steel for automotive applications) to 15 mm (ship steel) in thickness. The laser can be spaced above the surface 18 a distance, H, within the range of 150 to 200 mm and angled between 70° and 90° (i.e., angle between the laser head and vertical axis). The preferred laser 30 may also be a low powered CO₂ or fiber laser having an individual or simultaneous processing capacity. Finally, a flow of inert gas, such as Argon, may be directed along the seam at an angle within the range 20° to 60° and at a discharge rate within the range of 10 to 100 L/min.

[0021] The laser beam 30a may be produced by a single laser and delivered via fiber optic conduit and articulated robotic arms, in order to work on components of complex shape. The laser beam 30a may also be split into multiple beams configured to concurrently or sequentially act upon the same or different portions of the workpieces to produce a deeper weld or multiple concurrent welds. Finally, a plurality of systems 10 may be interconnected and simultaneously operable, so as to concurrently weld an equal plurality of sets of workpieces.

[0022] Thus, a preferred method of welding a plurality of workpieces to produce a weld is presented, and includes the following steps. First, a portion of the workpieces is heated to a temperature at least equal to 10% of the melting range of temperatures of the workpiece, by engaging each workpiece with an electrode and passing an electric current therebetween. More preferably, the portion is heated to 20% of the melting range for steel, and not less than 30% for aluminum alloys. Next, a laser beam engages and further heats the portion past the melting range of the workpiece material to form a weld pool. Where continuous welding is desired, the electrodes and beam are congruently translated. Finally, the molten material is cooled to a temperature less than the melting range and allowed to re-solidify. Multiple laser beams may be split from the initial beam and engage the workpieces either in series or in parallel.

[0023] Obvious modifications to the exemplary embodiments and methods of operation, as set forth herein, could be readily made by those skilled in the art without departing from the spirit of the present invention. As used herein, the term "plurality" shall mean two or more. The inventor hereby states his intent to rely on the Doctrine of Equivalents to determine and assess the reasonably fair scope of the present invention as pertains to any system not materially departing from but outside the literal scope of the invention as set forth in the following claims.

1. A system for welding a plurality of workpieces, said system comprising:
 - a heating unit configured to heat a first portion of the workpieces to a minimum temperature; and
 - a welding device configured to engage and further heat the first portion, said unit and device being cooperatively configured to weld said plurality of workpieces.
2. The system as claimed in claim 1, said unit including a first electrode configured to engage and transmit an electric current through a second portion of the workpieces.
3. The system as claimed in claim 2, said electrode and workpieces being cooperatively configured to heat the first portion to a temperature at least equal to 10% of the melting range of the first portion.
4. The system as claimed in claim 3, said electrode and workpieces being cooperatively configured to heat the first portion to a temperature at least equal to 50% of the melting range of the first portion.
5. The system as claimed in claim 2, said unit further including a second electrode spaced from the first electrode and configured to receive the electric current.
6. The system as claimed in claim 1, said unit and device each being linearly translatable, so as to form a continuous weld.
7. The system as claimed in claim 6, said unit including at least one electrode wheel.

said device including a laser configured to focus at least one laser beam upon the first portion.

9. The system as claimed in claim 8, said laser having a power output less than 4 kW.

10. The system as claimed in claim 8, said laser being either a YAG or CO₂ laser.

11. A system for in tandem welding of a plurality of workpieces, said system comprising:
first and second electrode wheels configured to cooperatively heat a first portion of the workpieces to a temperature at least equal to a predetermined percentage of the melting range of the first portion; and
a laser configured to engage and further heat the first portion,
said electrodes and laser being translatable relative to the workpieces, and
cooperatively configured to form a continuous weld between said plurality of workpieces.

12. The system as claimed in claim 11, said wheels and laser presenting a single-sided process, wherein said wheels and laser engage a single side of the workpieces.

13. A method of increasing the efficiency of laser-welding a plurality of workpieces, said method comprising the steps of:

- a) heating a portion of the workpieces to a minimum temperature using a heating unit;
- b) further heating the portion with a laser beam until the portion melts; and
- c) cooling the portion to a temperature less than the melting range and allowing the portion to re-solidify and form a weld.

14. The method as claimed in claim 13,
step (a) further including the steps of passing an electric current through the
workpieces to generate a quantity of heat energy.
15. The method as claimed in claim 13,
step (a) further including the steps of linearly translating the unit, step (b) further
including the steps of linearly translating the laser beam, and step (c) further
including the steps of allowing the formation of a continuous weld.
16. The method as claimed in claim 13, wherein steps (a) and (b) are
performed concurrently.

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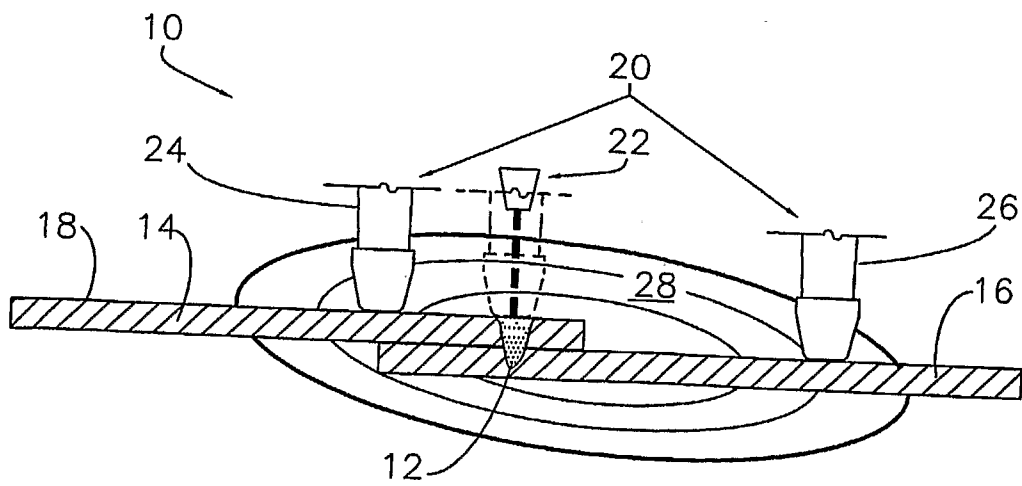


FIG. 1

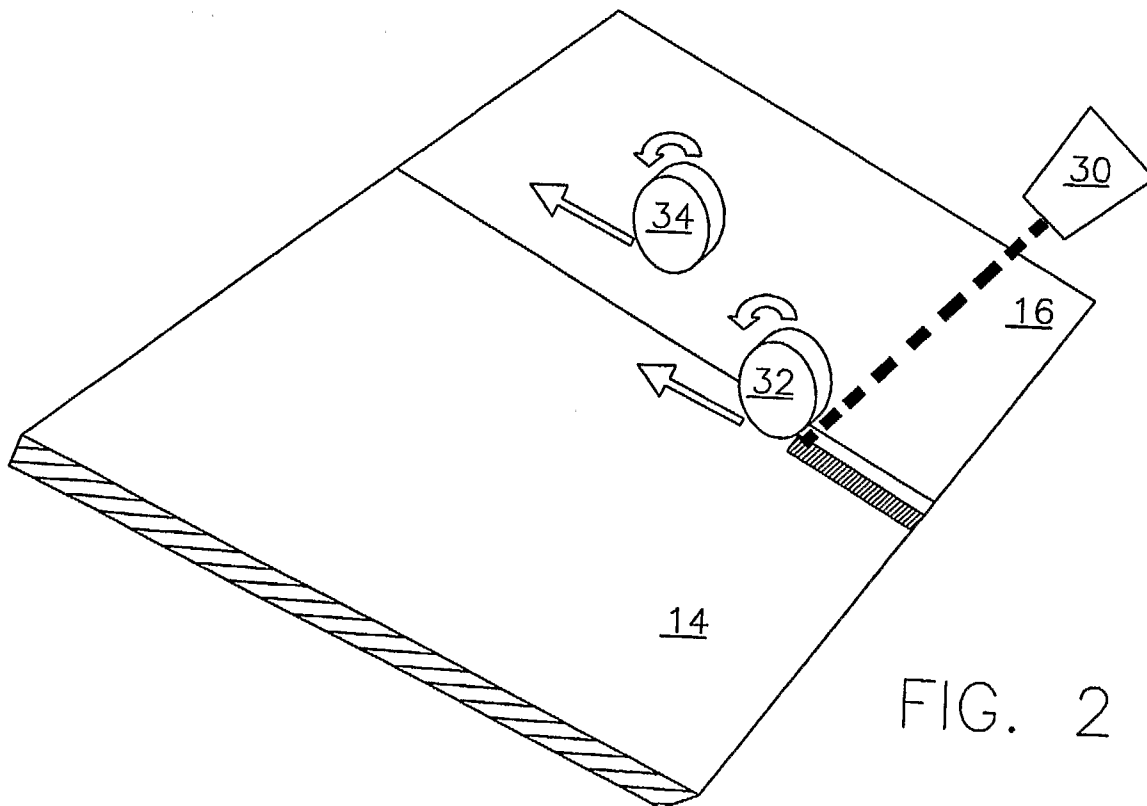


FIG. 2

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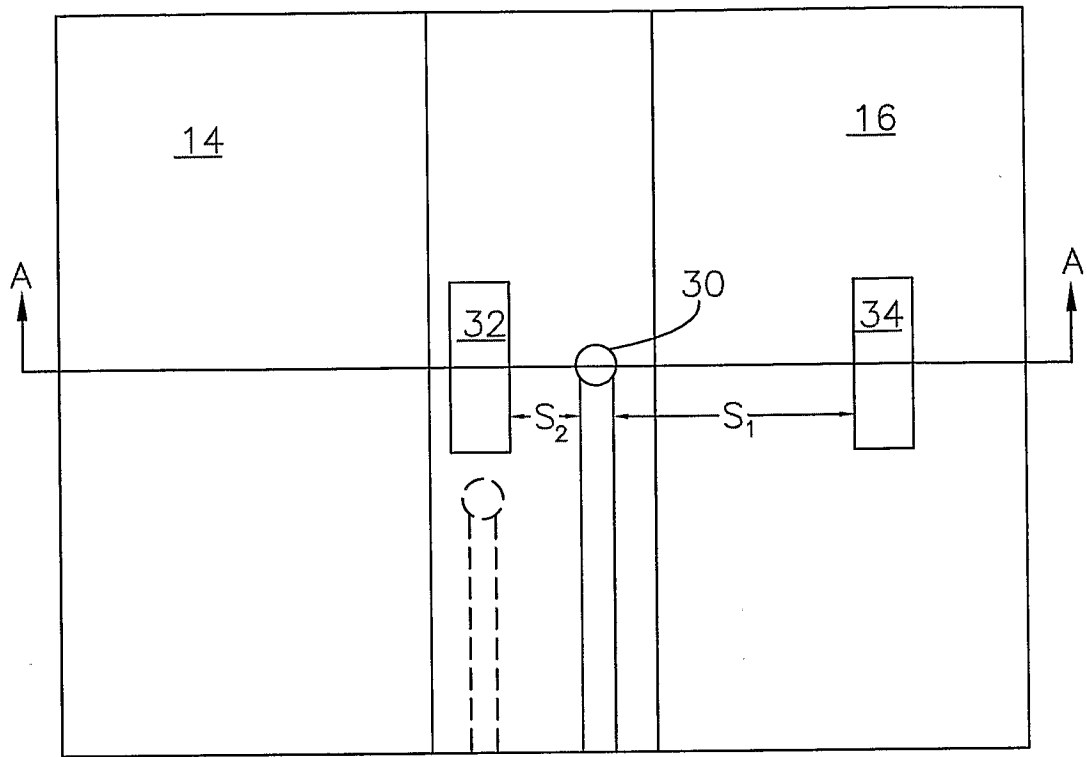


FIG. 3

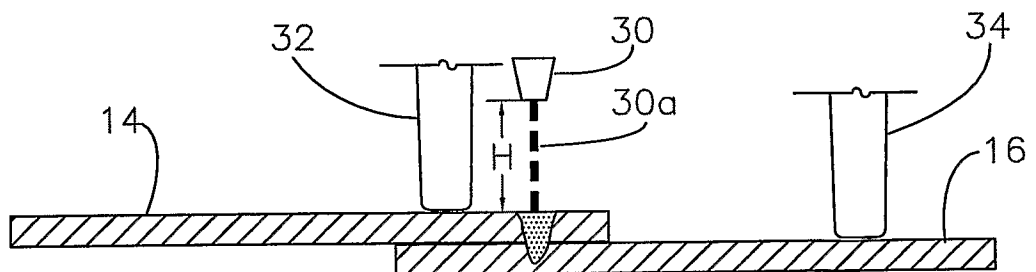


FIG. 4