



(43) International Publication Date
18 October 2012 (18.10.2012)

- (51) International Patent Classification:
B23K 28/02 (2006.01) *B23K 9/00* (2006.01)
B23K 26/00 (2006.01)
- (21) International Application Number:
PCT/CA2012/000366
- (22) International Filing Date:
13 April 2012 (13.04.2012)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/475,925 15 April 2011 (15.04.2011) US
- (71) Applicant (for all designated States except US): **MAGNA INTERNATIONAL INC.** [CA/CA]; 337 Magna Drive, Aurora, Ontario L4G 7K1 (CA).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **DEVERS, Terry** [CA/CA]; 1387 Kainswoods Terrace, London, Ontario L (CA). **HILL, John E.** [CA/US]; 11662 Watkins Dr., Shelby Twnshp, Michigan 48315 (US). **MISTRY, Harish** [—/US]; 6403 Country Ridge Dr., Troy, Michigan 48084 (US).
- (74) Agents: **BRANDT, Kerstin B.** et al.; Magna International Inc., 337 Magna Drive, Aurora, Ontario L4G 7K1 (CA).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: LASER WELDING ASSEMBLY AND METHOD

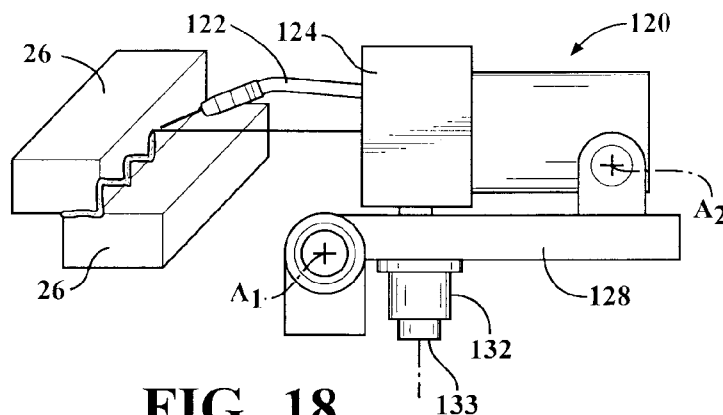


FIG. 18

(57) Abstract: A hybrid laser arc welding assembly including a gas metal arc welding torch and a laser arc welding laser head. The torch and laser head are disposed adjacent one another and aimed at targets of a pair of work pieces spaced from one another such that the melted material produced by the torch overlaps with the melted material produced by the laser head, and therefore, the torch and laser head combine to create a hybrid laser arc weld to join the work pieces. The laser head is adjustable dynamically relative to the work-pieces to optimize the hybrid laser arc weld.

LASER WELDING ASSEMBLY AND METHOD

CROSS-REFERENCE TO PRIOR APPLICATION

[0001] This PCT patent application claims the benefit of U.S. Provisional Patent Application Serial No. 61/475,925 filed April 15, 2011, entitled "Laser Welding Assembly
5 And Method," the entire disclosure of the application being considered part of the disclosure of this application and hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The subject invention is related to welding assemblies and methods. More
10 specifically, the subject invention is related to a laser welding assembly and method.

2. Description of the Prior Art

[0003] Two common welding processes for joining two or more metal components are gas metal arc welding (GMAW) and laser beam welding (LBW). During the GMAW process, a wire electrode is fed into a torch, which melts the wire electrode at the
15 intersection of, for example, two plates. The melted wire subsequently cools to join the two plates. A shielding gas is generally used to protect the welding area from atmospheric gasses which could otherwise compromise the integrity of the weld. Typical electrode wires are of silicon, manganese, titanium or aluminum materials, and typical shielding gases are inert gases, such as argon or helium. GMAW is sufficient for many applications, but
20 generally produces a relatively shallow weld profile, which often must be built up to achieve desired structural characteristics of the weld. GMAW is also limited by the speed at which the wire electrode can be melted to form the weld.

[0004] During the LBW process, a laser head produces a continuous or pulsed high power density laser beam to melt the materials being joined. The spot size of the laser beam
25 can be varied by adjusting the power wattage supplied to the laser head or by adjusting the focal point of the laser beam. LBW is advantageous because it can produce a weld with a deep penetration.

[0005] The combination of GMAW and LBW is generally referred to as hybrid laser arc welding (HLAW). The HLAW is advantageous since it results in an increase in both
30 weld penetration depth and welding speed when compared to each process alone. Different joint configurations (e.g. lap joint, butt joint, T-joint, corner joint or edge joint) have different optimum orientations of the torch and laser head. Typical HLAW assemblies are setup in a specific joint configuration and can only be adjusted between welding operations

with physical/manual effort, thereby limiting the effectiveness and the efficiency of the HLAW process.

[0006] There remains a significant and continuing need for an improved welding assembly for welding various joint configurations.

5

SUMMARY OF THE INVENTION

[0007] One aspect of the subject invention provides for a laser welding assembly and method for welding various joint configurations with a dynamically adjustable laser head. With the dynamically adjustable laser head, the assembly can efficiently and quickly weld plates of various materials (e.g., steel, aluminum and/or magnesium) into many different joint configurations. Further, the laser head can be moved to different angles on-the-fly during the welding operation to optimize the weld to weld complicated patterns. For example, dynamic adjustments of the laser head can adjust the amount of melt produced by the laser beam and/or the penetration of the laser beam during a single welding operation. Moreover, the laser head can be dynamically moved in a weaving pattern, which further increases the amount of melt produced by the laser beam along a joint.

10

[0008] The laser welding assembly could also be a hybrid laser arc welding (HLAW) assembly having a dynamically adjustable laser head and a torch which could either be non-adjustable or dynamically adjustable. If the torch is dynamically adjustable, it can either be adjusted along with the laser head or independent of the laser head to optimize the welding process.

15

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] 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:

25 [0010] Figure 1 is a top view of a first exemplary embodiment of the hybrid laser arc welding assembly;

[0011] Figure 2 is a side view of both the torch and the laser head welding a lap joint at approximately a 45° angle;

[0012] Figure 3 is a side view of the torch welding a lap joint at approximately a 45° angle and the laser head welding the lap joint at a greater than 45° angle;

30

[0013] Figure 4 is a side view of the torch welding a lap joint at approximately a 45° angle and the laser welding the lap joint at approximately a 90° angle;

- [0014] Figure 5 is a side view showing three possible orientations of the laser head for welding a lap joint;
- [0015] Figure 6 is a side view showing three possible orientations of the laser head for welding a lap joint;
- 5 [0016] Figure 7 is a side view showing three possible orientations of the laser head for welding a butt joint;
- [0017] Figure 8 is a side view of an exemplary torch;
- [0018] Figure 9 is a top view of a second exemplary embodiment of the hybrid laser arc welding assembly;
- 10 [0019] Figure 10 is a side view of the second exemplary embodiment of the hybrid laser arc welding assembly showing the torch mounted to a plate;
- [0020] Figure 11 is a top view of a third exemplary embodiment of the hybrid laser arc welding assembly;
- [0021] Figure 12 is a side view of one of one of the exemplary embodiments of the hybrid laser arc welding assembly and showing the laser head oriented at approximately a 45° angle;
- 15 [0022] Figure 13 is a side view of one of the exemplary embodiments of the hybrid laser arc welding assembly and showing the laser head oriented at a small angle;
- [0023] Figure 14 is a side view of one of the exemplary embodiments of the hybrid laser arc welding assembly and showing the laser head oriented at approximately a 90° angle;
- 20 [0024] Figure 15 is a side view of one of the exemplary embodiments of the hybrid laser arc welding assembly and showing the laser head oriented at a small angle;
- [0025] Figure 16 is a side view of one of the exemplary embodiments of the hybrid laser arc welding assembly and showing the laser head oriented at approximately a 90° angle;
- 25 [0026] Figure 17 is a side view of one of the exemplary embodiments of the hybrid laser arc welding assembly with the laser head moving through a weaving pattern;
- [0027] Figure 18 is another side view of one of the exemplary embodiments of the hybrid laser arc welding assembly with the laser head moving through a weaving pattern;
- 30 [0028] Figure 19 is another side view of one of the exemplary embodiments of the hybrid laser arc welding assembly with the laser head moving through a weaving pattern;

[0029] Figure 20 is a side view of one of the exemplary embodiments of the hybrid laser arc welding assembly with the laser head moving through a curved pattern;

[0030] Figure 21 is another side view of one of the exemplary embodiments of the hybrid laser arc welding assembly with the laser head moving through a curved pattern;

5 [0031] Figure 22 is a side view of one of the exemplary embodiments of the hybrid laser arc welding assembly with the laser head moving through a stitching pattern;

[0032] Figure 23 is another side view of one of the exemplary embodiments of the hybrid laser arc welding assembly with the laser head moving through a stitching pattern; and

10 [0033] Figure 24 is a side view of an exemplary tool center position calibrating setup.

DETAILED DESCRIPTION OF THE ENABLING EMBODIMENTS

[0034] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, an exemplary hybrid laser arc welding (HLAW) assembly 20 for producing a hybrid laser arc weld between at least two work pieces is generally shown in Figure 1. The HLAW assembly 20 includes a torch 22 for gas-metal arc welding (GMAW) and a laser head 24 for laser beam welding (LBW). As will be discussed in greater detail below, the HLAW assembly 20 is dynamically adjustable to weld plates 26 (or any other types of metallic work pieces) into a variety of different joint configurations, such as lap joints (Figures 2-6), butt joints (Figure 7), T-joints (not shown), corner joints (not shown) or edge joints (not shown). The components being joined can be of any desirable type of metal including, for example, steel, aluminum, magnesium and various alloys.

[0035] In operation, the HLAW assembly 20 is first positioned in front of an intersection between the plates 26 to be welded. The torch 22 and laser head 24 are then activated, and the HLAW assembly 20 is moved in a direction of travel along the interface of the two plates 26 by a robot (not shown). It may be desirable for the laser head 24 to lead the movement along the interface so that it can produce a deep penetrating weld while the torch 22 eliminates any undercutting in the materials. However, the torch 22 could lead the movement if desired.

[0036] The laser wattage and spot size of the laser head 24 are preferably chosen based on the material(s) being welded, the material thickness and the joint configuration. For example, the settings for the laser head 24 could be five kilowatts (5 kw) of power and a

spot size of six hundred micrometers (600 μm) to weld one particular joint. Likewise, the shielding gas and the material of the wire electrode for the torch 22 are chosen based on the material of the plates 26 being welded, the plate thickness, the joint configuration, the wire electrode diameter, the wire feed speed, the travel speed, the power source type (direct
5 current or alternating current) and the torch angle.

[0037] In the first embodiment of the HLAW assembly 20, as shown in Figure 1, the torch 22 is mounted directly on the robot 27 (also shown in Figure 8), and the laser head 24 is mounted on a table 28, which is attached to the robot 27. The torch 22 and laser head 24 are angled toward one another such that they are aimed at a point on the joint to be welded
10 adjacent to one another. The torch 22 and laser head 24 are preferably angled relative to one another such that they are aimed at targets adjacent one another such that the melted material produced by the torch 22 overlaps with the melted material produced by the laser head 24 to produce a hybrid laser arc weld between the plates 26. Most preferably, the torch 22 and laser head 24 are aimed at targets with approximately a two millimeter (2 mm)
15 pitch, or gap, between one another. This pitch may be beneficial since it allows both the torch 22 and laser head 24 to pass an area of the joint without the metal cooling therebetween. Alternately, the pitch between the torch 22 and laser head 24 could be less than four millimeters (4 mm). Both the torch 22 and laser head 24 are preferably positioned such that the push or drag angles of the torch 22 and laser head 24 are approximately fifteen
20 degrees (15°). The table 28 of the first exemplary embodiment is rotatably coupled to the robot 27 about a first axis A₁, and a first servo motor 30 is operatively connected to the table 28 for rotating the table 28 relative to the robot 27. In the first exemplary embodiment, the first servo motor 30 is configured to rotate the table 28 to any orientation from a zero degree (0°) angle as shown in Figure 13 to a ninety degree (90°) angle as shown
25 in Figure 16. A tool centering point (TCP) calibration may be performed each time the table 28 is rotated, between welding operations, or periodically to ensure a proper alignment of the torch 22 and the laser head 24.

[0038] As shown in Figure 2, both the laser head 24 and the torch 22 are aimed at a lap joint formed between the plates 26 at approximately a forty-five degree (45°) angle. In
30 Figure 3, the table 28 supporting the laser head 24 has been rotated upwardly and the laser beam is striking the lap joint formed between the plates 26 at an angle greater than forty-five degrees (>45°). In Figure 4, the table 28 supporting the laser head 24 has been rotated to a ninety degree (90°) degree angle. These are three orientations that are possible with the

first exemplary embodiment because the orientation of the table 28 can be quickly and dynamically adjusted with the first servo motor 30, thereby altering the orientation of the laser head 24 relative to the torch 22. These adjustments can be made during a welding process or between welding processes.

5 [0039] Referring now to Figures 5 and 6, three possible programmable angles of the laser head 24 for welding two plates 26 with a lap joint configuration are shown. The letter “A” designates a steep angle, the letter “B” designates a medium angle and the letter “C” designates a shallow angle. When the laser head 24 is oriented at the steep angle position (“A”), the laser beam will strike the upper of the plates 26 and create a volume of melt to
10 help bridge the gap between the plates 26. The torch 22 then joins the melt with the lower of the plates 26 to strengthen the weld joint between the plates 26. When the laser head 24 is oriented at the medium angle position (“B”), the laser beam will strike the lower corner of the upper of the plates 26 and create a melt, which fills the gap between the plates 26. This will also provide for a deeper penetration by the laser beam at the interface of the two plates
15 26 as compared to the steep angle described above. Simultaneously to the laser beam creating the melt, the torch 22 fills any undercut produced by the laser. When the laser head 24 is oriented at the shallow angle position (“C”), the laser beam will produce a deep penetrating weld into the intersection of the two plates 26. Simultaneously, the torch 22 caps the weld with a bead and eliminates any undercutting. With the servo motor 30, the
20 laser head 24 can quickly and dynamically be moved between positions “A”, “B” and “C” to achieve the desired weld while the torch 22 is held at a constant orientation relative to the plates 26. A camera (not shown) or any type of sensor can be used to monitor the condition of the weld, and the orientation of the laser head 24 can be dynamically adjusted according to the condition of the weld.

25 [0040] Referring now to Figure 7, three possible programmable angles of the laser head 24 for welding two plates 26 with a butt joint configuration are shown. Similar to Figures 5 and 6, the letter “A” designates a steep angle, the letter “B” designates a medium angle and the letter “C” designates a shallow angle. When the laser head 24 is oriented at the steep angle position (“A”), the laser beam will produce a deep penetrating weld into the
30 intersection of the two plates 26 to be welded. Simultaneously, the torch 22 can be held at a ninety degree (90°) angle to cap the weld with a bead and eliminate any undercutting. When the laser head 24 is oriented at the medium angle position (“B”), the laser beam strikes one of the plates 26 and creates a melt to fill the gap between the plates 26 being

welded. Simultaneously to the laser beam creating the melt, the torch **22** fills any undercut produced by the laser beam. When the laser head **24** is oriented at the shallow angle position ("C"), the laser beam strikes one of the plates **26** and creates a volume of melt to help bridge the gap between the two plates **26** being welded.

5 **[0041]** The laser head **24** can also be in communication with a controller (not shown) which controls the spot size of the laser beam and the power supplied to the laser head **24**. A larger spot size has been found to stabilize the arc of the torch **22**, whereas a narrower spot size generally produces a deeper weld penetration. A narrower spot size also tends to allow for higher travel speeds and thus, quicker welds.

10 **[0042]** A second exemplary embodiment of the HLAW assembly **120** is generally shown in Figures 9 and 10. In this exemplary embodiment, the torch **122** and laser head **124** are mounted on a common table **128**. This arrangement allows the torch **122** and the laser beam to maintain a substantially constant pitch and orientation with respect to one another. The table **128** of the second exemplary embodiment is rotatably coupled to the
15 robot **127** about a first axis **A₁**, and a first servo motor **130** is operatively connected to the table **128** for rotating the table **128**. In this configuration, only a single TCP calibration is typically necessary to calibrate both the torch **122** and the laser head **124**. The second embodiment is advantageous because it allows the torch **122** and laser head **124** to be quickly and dynamically adjusted together to weld any desirable joint configuration.

20 **[0043]** Referring now to Figure 11, a third exemplary embodiment of the HLAW assembly **220** is generally shown. In this embodiment, the torch **222** and laser head **224** are mounted on separate tables **228**, each independently rotatable about the first axis **A₁**. A first servo motor **230** is operatively coupled to the table **228** supporting the torch **222** for rotating the torch **222**, and a second servo motor **230** is operatively coupled to the table **228**
25 supporting the laser head **224** for rotating the laser head **224**. A TCP calibration may be performed for each movement of either table **228** in order to calibrate the torch **222** and laser head **224** separately. The third embodiment is advantageous because it allows the torch **222** and laser head **224** to be dynamically adjusted independently of one another to optimize the weld for any desirable joint configuration.

30 **[0044]** Figures 12-24 show additional features of the second exemplary embodiment, though these features are also applicable to the first and third exemplary embodiments. A trunnion **132**, or a lift, could be operatively coupled to the laser head **124** for rotating the laser head **124** about a second axis **A₂**. A trunnion servo motor **133** is

operatively coupled to the trunnion **132** for controlling the amount of rotation of the laser head **124** about the second axis A_2 . With the trunnion **132** and the trunnion servo motor **133**, the laser head **124** can be swung independently of the torch **122** and can be oriented to heat the plates **26** at an angle independent of the torch **122**. The trunnion **132** could be moved to reposition the laser head **124** either after the table **128** is adjusted or simultaneous to the dynamic adjustment of the table **128**. Thus, the trunnion **132** and trunnion servo motor **133** provide an additional degree of freedom for adjusting the laser head **124**.

[0045] Since the trunnion **132** is coupled to the laser head **124** of the second embodiment (with the torch **122** and laser head **124** mounted on a common table **128**), the table **128** could be reciprocated in opposite directions to move the torch **122** in a “weaving” motion and produce a thicker weld. While the common table **128** is being reciprocated, the trunnion servo motor **133** could function to hold the laser head **124** steady, and therefore, the laser head **124** continues to produce a deep weld between the plates **26**. In other words, during this process, the torch **122** is weaving while the laser beam moves in a straight line with the trunnion servo motor **133** countering the reciprocation of the common table **128** supporting both the torch **122** and the laser head **124**.

[0046] Alternatively, the laser head **124** can be moved in a weaving motion by the trunnion servo motor **133** while the torch **122** remains in a constant orientation. This could be advantageous in creating additional melt with the laser beam without increasing spot size, which would otherwise result in reduced weld penetration. When additional melt is no longer required, the trunnion servo motor **133** could stop the weaving motion. Figures 17-19 show the laser head **124** producing such a weaving pattern. Alternately, as shown in Figures 20-21, the laser head **124** could be guided to follow a curve or a feature in a part to be welded while the torch **122** is maintained in a stable orientation. Even further, as shown in Figures 22-23, the laser head **124** could be moved to perform a stitch operation while the torch **122** is maintained in a stable orientation or vice versa.

[0047] Referring now to Figure 24, an exemplary laser TCP station **135** for calibrating the laser head **124** is shown. The TCP station **135** includes two spaced alignment plates **134** of a low melting point material, e.g. aluminum. During the initial setup of the TCP station **135**, alignment holes are burned into these plates **134** with the laser head **124**. A temperature sensor **136** is then aligned with the two alignment holes in the alignment plates **134**. During the TCP process, the laser head **124** is moved into the position shown in Figure 24, and the laser head **124** is activated. If the laser beam passes

through both of the alignment holes, then the temperature sensor **136** will report that the laser head **124** is properly aligned. If the temperature sensor **136** does not detect the laser beam, then the laser head **124** is either not functioning properly or is misaligned and must be re-aligned to calibrate the assembly **120**.

- 5 **[0048]** The foregoing invention has been described in accordance with the relevant legal standards, thus the description is exemplary rather than limiting in nature. Variations and modifications to the disclosed embodiment may become apparent to those skilled in the art and fall within the scope of the invention.

CLAIMS

In The Claims:

1. A hybrid laser arc welding assembly, comprising:
a laser head for producing a laser beam to melt material of at least two metal
5 work pieces to be joined;
a torch having a wire electrode for forming a metal arc between said wire
electrode and the at least two work pieces to melt material of the at least two work pieces;
said laser head and said torch being aimed at targets adjacent one another
such that the melted material produced by said laser head overlaps with the melted material
10 produced by said torch to produce a hybrid laser arc weld between the at least two work
pieces; and
a servo motor operably coupled to said laser head for dynamically adjusting
the orientation of said laser head to optimize the hybrid laser arc weld produced by the
combination of said laser head and said torch.
15
2. The hybrid laser arc welding assembly as set forth in claim 1 wherein
said laser head and said torch are aimed at targets separated by a pitch of no greater than
two millimeters.
- 20 3. The hybrid laser arc welding assembly as set forth in claim 1 further
including a table supporting said laser head and pivotable about a first axis by said servo
motor.
4. The hybrid laser arc welding assembly as set forth in claim 3 wherein
25 further including a trunnion and a trunnion servo motor operably coupled to said table and
said laser head for pivoting said laser head about a second axis spaced from said first axis.
5. The hybrid laser arc welding assembly as set forth in claim 3 wherein
both said laser head and said torch are supported by said table.
30
6. The hybrid laser arc welding assembly as set forth in claim 3 wherein
said laser head and said torch are supported by separate tables dynamically adjustable
independent of one another.

7. The hybrid laser arc welding assembly as set forth in claim 1 wherein said torch and laser head are angled relative to one another.

5 8. The hybrid laser arc welding assembly as set forth in claim 1 wherein said torch and laser head are operably coupled to a robot for moving relative to the work pieces.

9. A method of welding at least two work pieces together, comprising
10 the steps of:
aiming a laser beam welding laser head at target along the intersection of the work pieces;
aiming a gas metal arc welding torch at another target separated from the target of the laser head by a predetermined pitch;
15 activating the torch and the laser head to produce a hybrid laser arc weld between the work pieces; and
dynamically adjusting the orientation of the laser head with both the laser head and the torch activated.

20 10. The method as set forth in claim 9 further including the step of dynamically adjusting the orientation of the torch with both the laser had and the torch activated.

11. The method as set forth in claim 10 wherein the adjusting of the laser
25 head is independent of the adjusting of the torch.

12. The method as set forth in claim 9 wherein the adjusting of the orientation of the laser head is further defined as pivoting the laser head about a first axis.

30 13. The method as set forth in claim 12 further including pivoting the orientation of the laser head about a second axis spaced from the first axis.

14. The method as set forth in claim 9 further including either the step of moving the laser head and torch relative to the work piece.

- 5 15. The method as set forth in claim 14 further including the step of oscillating the laser head in opposite directions while holding the torch at a constant orientation during the movement of the laser head and torch relative to the work pieces.

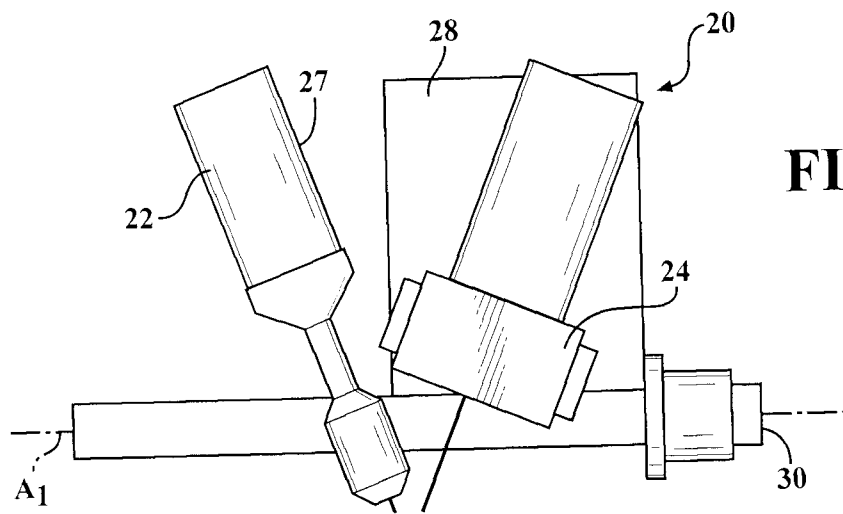


FIG. 1

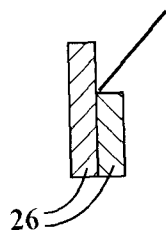


FIG. 2

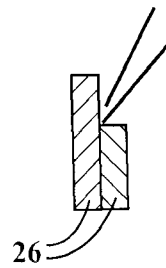


FIG. 3

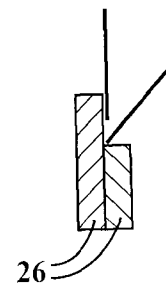


FIG. 4

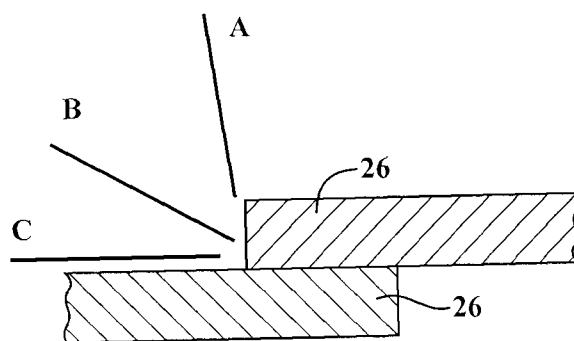


FIG. 5

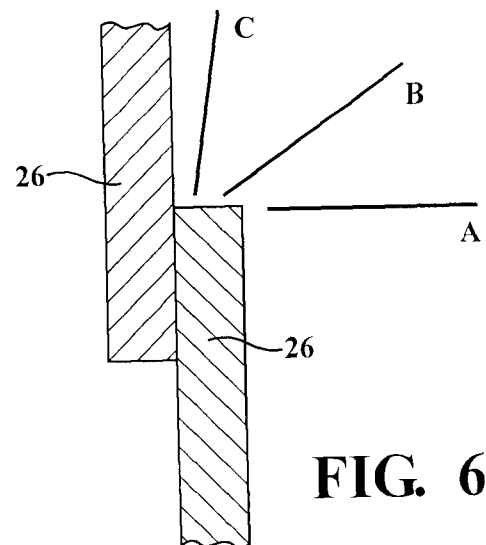


FIG. 6

FIG. 7

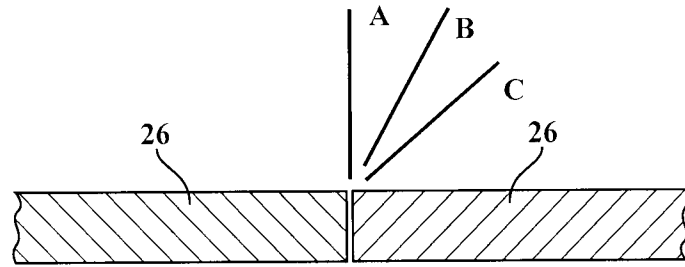


FIG. 8

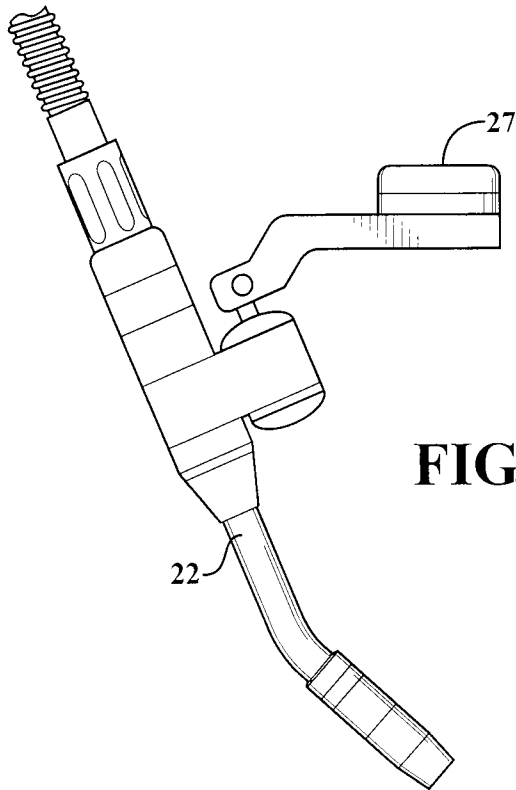
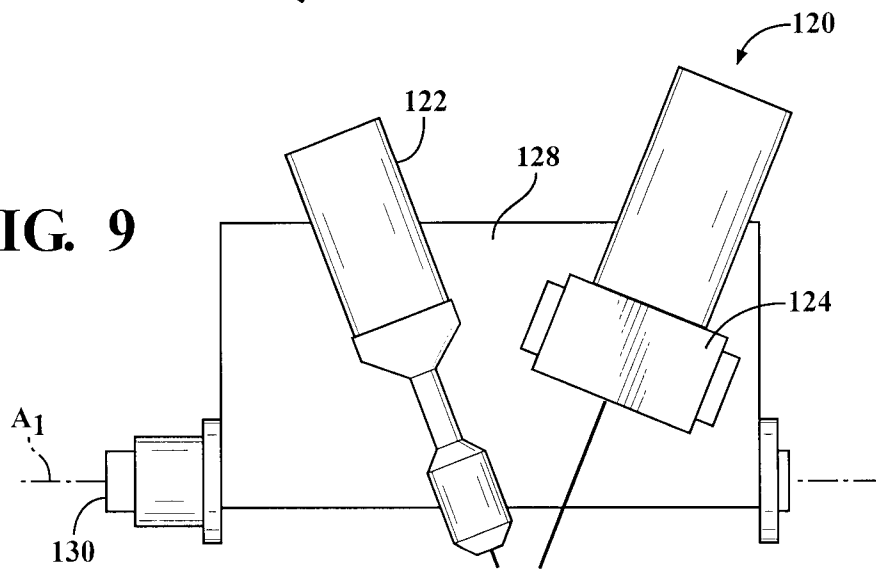
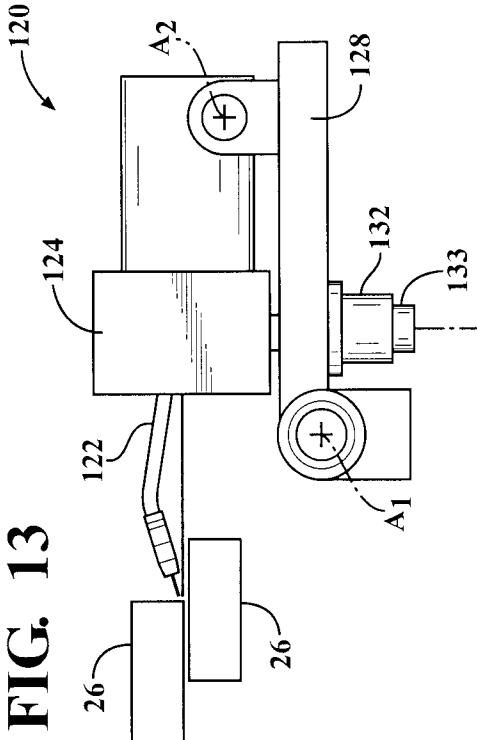
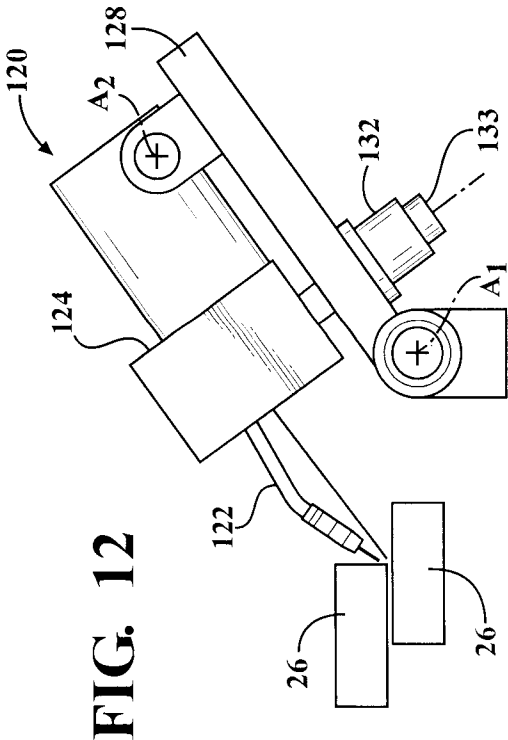
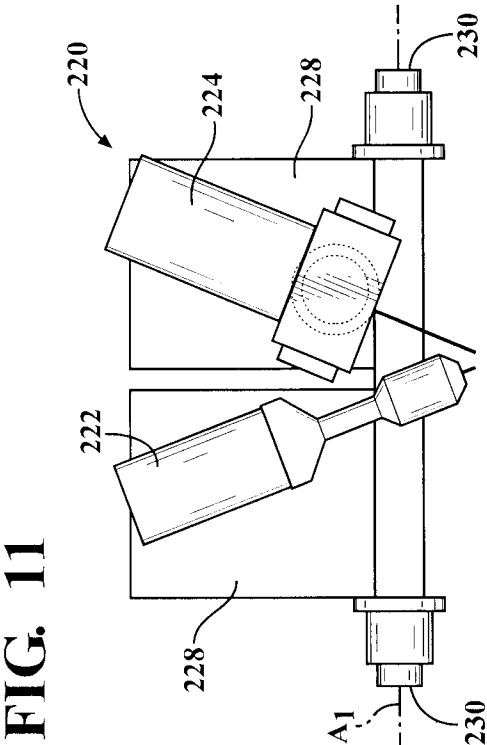
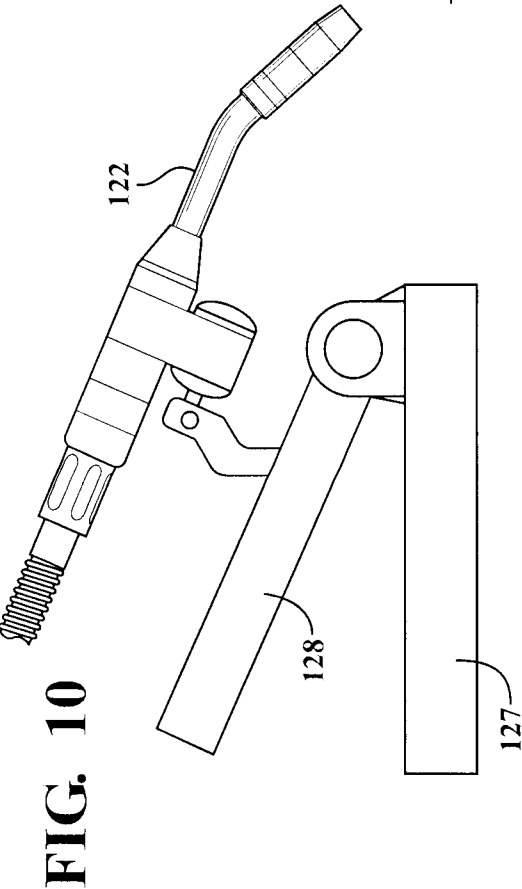


FIG. 9





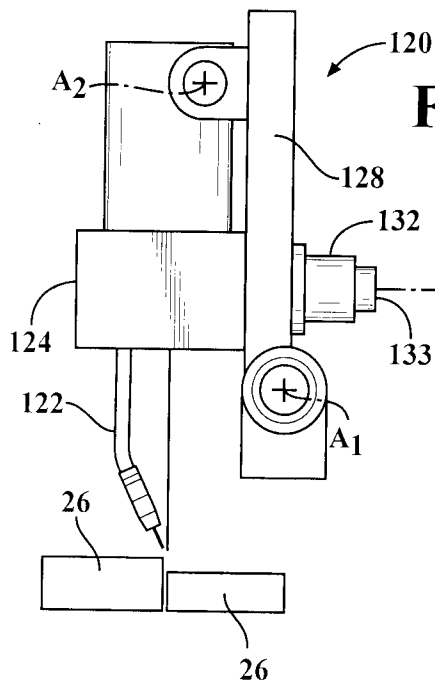


FIG. 14

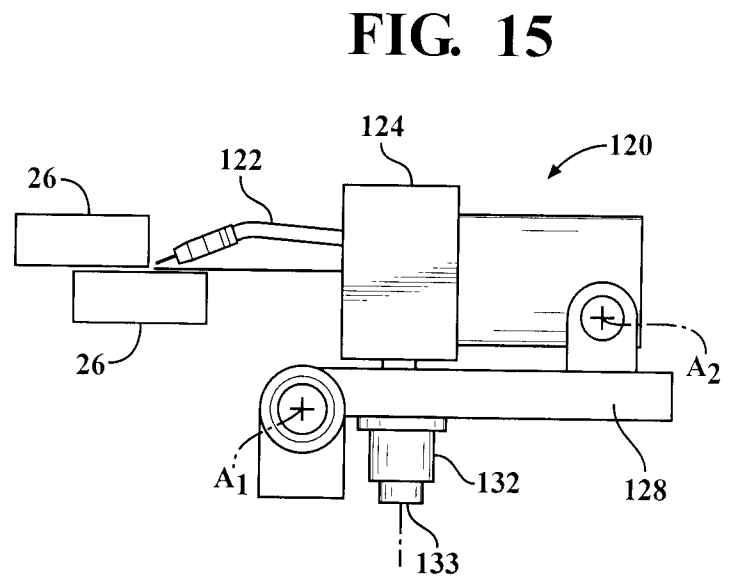


FIG. 15

FIG. 16

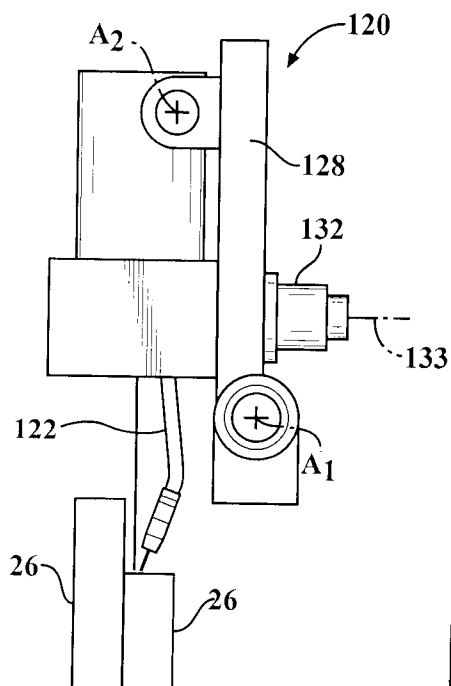
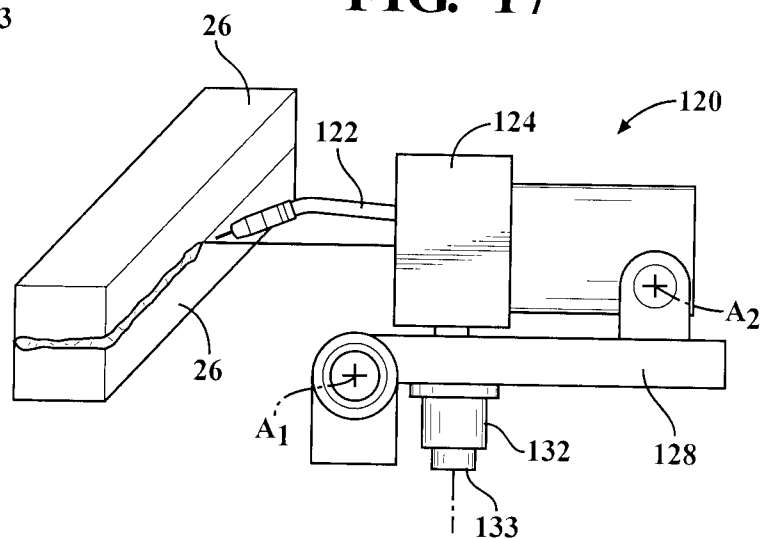


FIG. 17



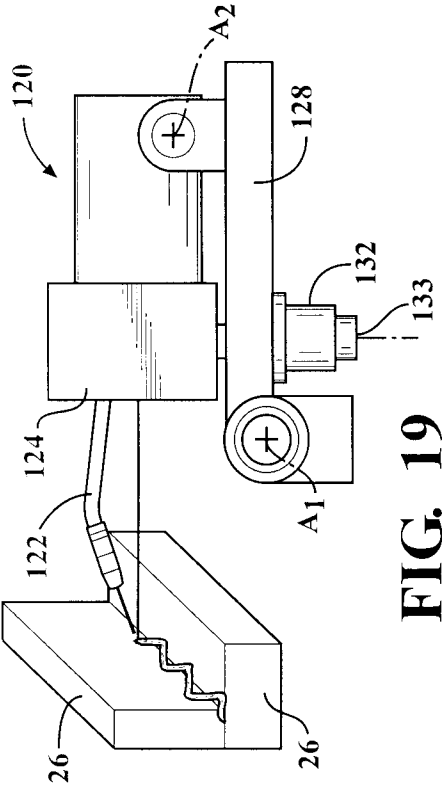


FIG. 19

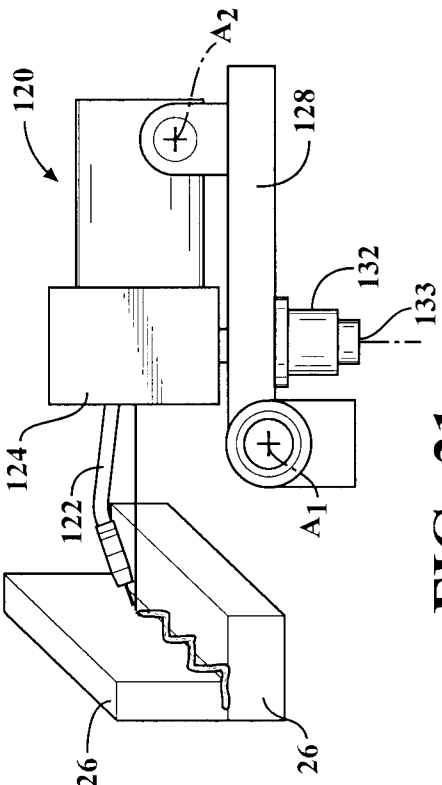


FIG. 21

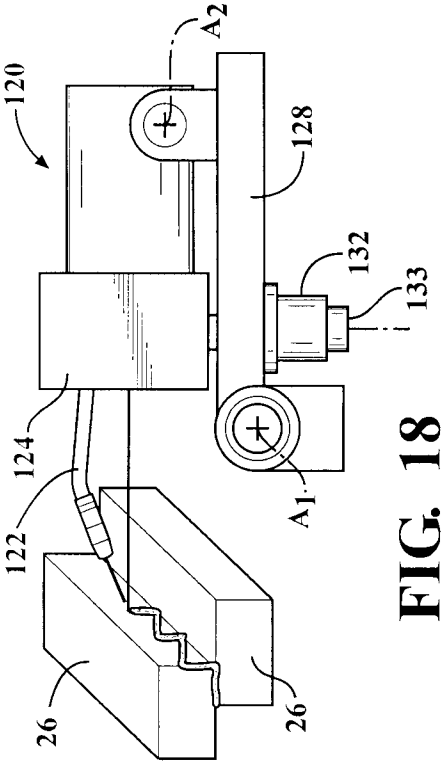


FIG. 18

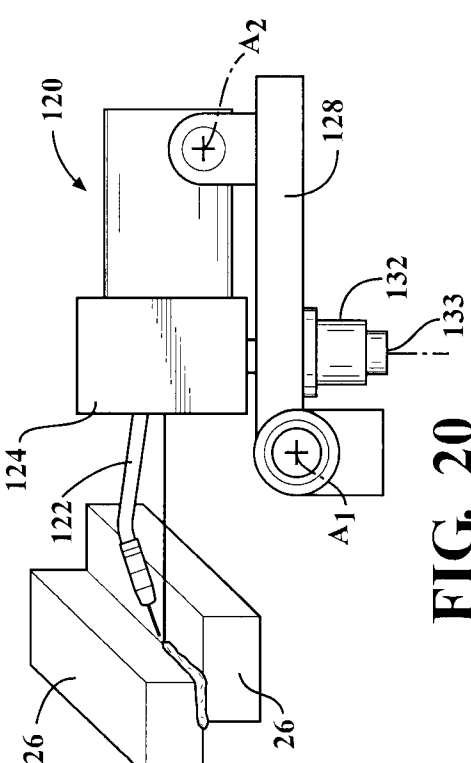
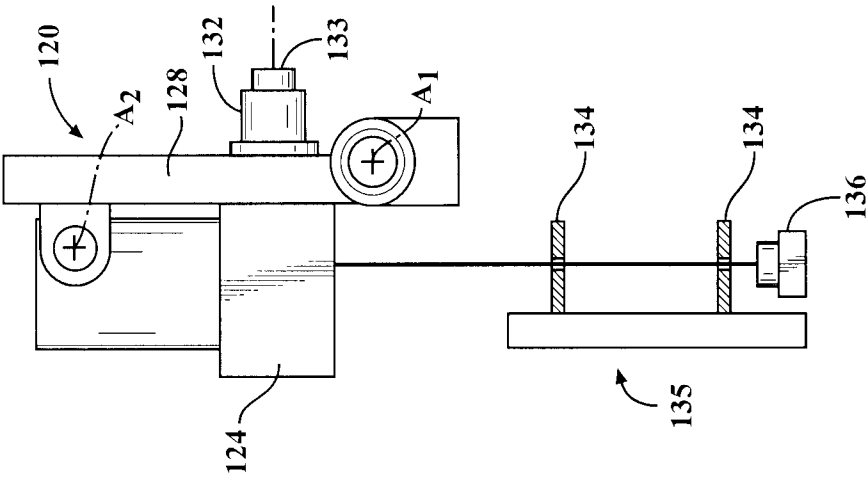
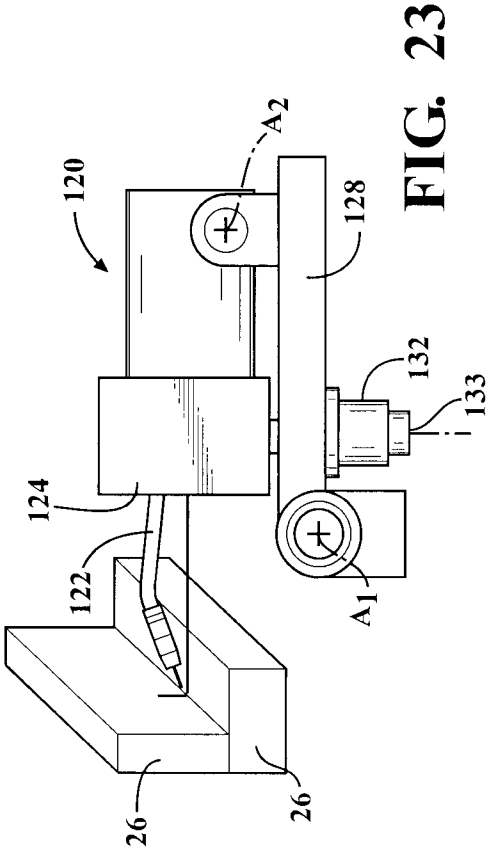
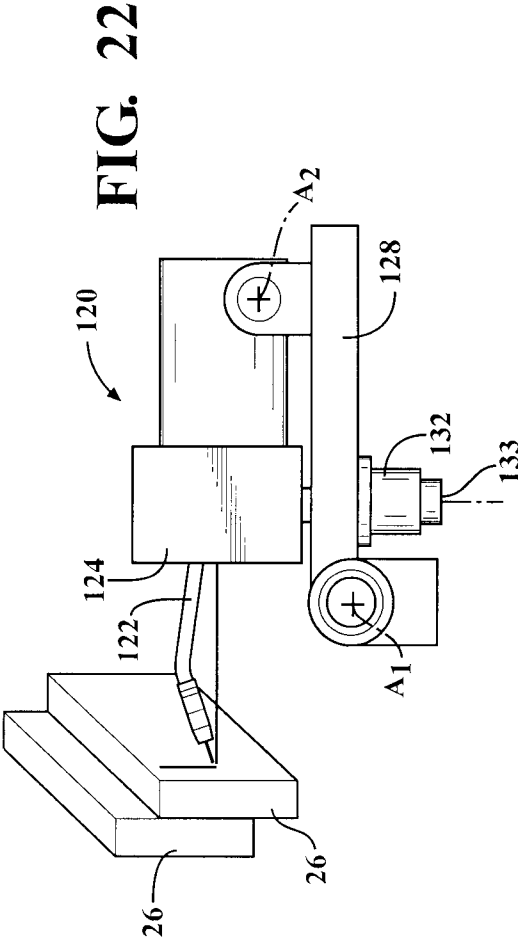


FIG. 20



INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2012/000366

A. CLASSIFICATION OF SUBJECT MATTER

IPC: **B23K 28/02** (2006.01) , **B23K 26/00** (2006.01) , **B23K 9/00** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC (2006.01): B23K, G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

TotalPatent, EPOQUE, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO0138038A2 (STAUFER et al.) 31 May 2001 (31-05-2001) *full document, machine translation*	9, 10, 14
Y		1-8, 11-13, 15
Y	US2001008231A1 (BRITNELL) 19 July 2001 (19-07-2001) *full document*	1-5, 7, 8, 12, 13
Y	US2003108234A1 (FUJITA et al.) 12 June 2003 (12-06-2003) *full document*	1-5, 7, 8, 12, 13
Y	US2010320174A1 (HYBINETTE et al.) 23 December 2010 (23-12-2010) *Figs. 3, 4A-4C*	6, 11
Y	CN101716701A (CHEN et al.) 02 June 2010 (02-06-2010) *Abstract, Fig. 3*	9, 14, 15
A	KR1020060012809A (SHIN) 09 February 2006 (09-02-2006) *full document, machine translation*	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

14 August 2012 (14-08-2012)

Date of mailing of the international search report

17 August 2012 (17-08-2012)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 001-819-953-2476

Authorized officer

Zoran Novakovic (819) 956-0843

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2012/000366

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2001008231A1	19 July 2001 (19-07-2001)	US5925268A US5961858A US6452131B2	20 July 1999 (20-07-1999) 05 October 1999 (05-10-1999) 17 September 2002 (17-09-2002)
US2003108234A1	12 June 2003 (12-06-2003)	CA2403596A1 CA2403596C CN1421293A CN1228169C DE60225655D1 DE60225655T2 EP1314510A1 EP1314510B1 JP2003164987A JP3806342B2 US7239736B2	26 May 2003 (26-05-2003) 25 November 2008 (25-11-2008) 04 June 2003 (04-06-2003) 23 November 2005 (23-11-2005) 30 April 2008 (30-04-2008) 23 April 2009 (23-04-2009) 28 May 2003 (28-05-2003) 19 March 2008 (19-03-2008) 10 June 2003 (10-06-2003) 09 August 2006 (09-08-2006) 03 July 2007 (03-07-2007)
US2010320174A1	23 December 2010 (23-12-2010)	US2010320174A1 WO2010148193A1	23 December 2010 (23-12-2010) 23 December 2010 (23-12-2010)
WO0138038A2	31 May 2001 (31-05-2001)	AT342147T AT371518T ATA196999A AT409602B ATA19362000A AT410067B AU1679301A AU5993401A CN1474731A CN100496857C CN1769000A CN100560269C CN101003108A CN101003108B DE50111224D1 DE50112941D1 DE50115005D1 DE20080266U1 EP1337375A1 EP1337375B1 EP1607167A1 EP1607167B1 EP1609556A1 EP1609556B1 ES2273840T3 ES2293428T3 JP2004512965A US2004026388A1 US6844521B2 WO0138038A2 WO0138038A3 WO0240211A1	15 November 2006 (15-11-2006) 15 September 2007 (15-09-2007) 15 February 2002 (15-02-2002) 25 September 2002 (25-09-2002) 15 June 2002 (15-06-2002) 27 January 2003 (27-01-2003) 04 June 2001 (04-06-2001) 27 May 2002 (27-05-2002) 11 February 2004 (11-02-2004) 10 June 2009 (10-06-2009) 10 May 2006 (10-05-2006) 18 November 2009 (18-11-2009) 25 July 2007 (25-07-2007) 08 September 2010 (08-09-2010) 23 November 2006 (23-11-2006) 11 October 2007 (11-10-2007) 03 September 2009 (03-09-2009) 04 October 2001 (04-10-2001) 27 August 2003 (27-08-2003) 11 October 2006 (11-10-2006) 21 December 2005 (21-12-2005) 22 July 2009 (22-07-2009) 28 December 2005 (28-12-2005) 29 August 2007 (29-08-2007) 16 May 2007 (16-05-2007) 16 March 2008 (16-03-2008) 30 April 2004 (30-04-2004) 12 February 2004 (12-02-2004) 18 January 2005 (18-01-2005) 31 May 2001 (31-05-2001) 14 February 2002 (14-02-2002) 23 May 2002 (23-05-2002)
CN101716701A	02 June 2010 (02-06-2010)	None	
KR1020060012809A	09 February 2006 (09-02-2006)	None	