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(54) **Title**: HOT-WIRE CONSUMABLE INCAPABLE OF SUSTAINING AN ARC

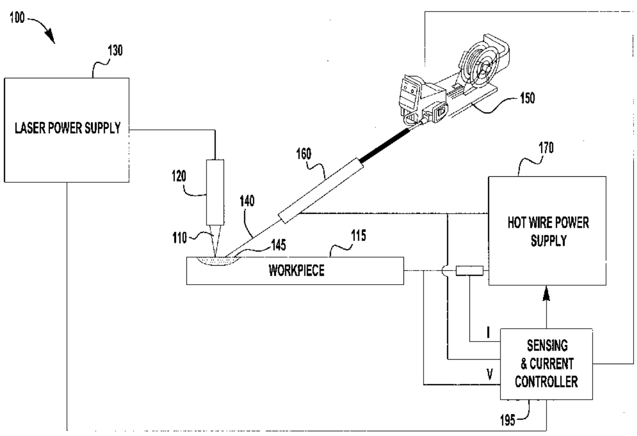

FIG. 1

(57) **Abstract**: A system (100) and method for using filler wire (140, 140A, 140B, 140C) in hot wire applications, e.g., brazing, cladding, building up, filling, overlaying, welding, and joining applications, is provided. The filler wire (140, 140A, 140B, 140C) has a first section that has a first resistance per unit length. The filler wire (140, 140A, 140B, 140C) has a second section that has a second resistance per unit length, which is higher than the first resistance per unit length. The second section of the filler wire is configured to melt before the first section during hot-wire applications. In some embodiments, a resistivity of the first section and a resistivity of the second section are equal and the second section has a cross-sectional area that is smaller than a cross-sectional area of the first section. In some embodiments, a resistivity of filler material in the first section and a resistivity of filler material in the second section are different.

HOT-WIRE CONSUMABLE INCAPABLE OF SUSTAINING AN ARC

[001] The present application claims priority to U.S. Provisional Patent Application No. 61/668,849 filed July 6, 2012, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[002] The invention is related to a filler wire for use in hot-wire applications according to claim 1, to a hot-wire system according to claim 10 and to a method of using filler wire in a hot-wire system according to claim 14. Certain embodiments relate to a filler wire used in overlaying, welding, and joining applications. More particularly, certain embodiments relate to a system and method that uses a filler wire of varying resistance in a system for any of brazing, cladding, building up, filling, hard-facing overlaying, joining, and welding applications.

TECHNICAL BACKGROUND

[003] The traditional filler wire method of welding (e.g., a gas-tungsten arc welding (GTAW) filler wire method) can provide increased deposition rates and welding speeds over that of traditional arc welding alone. In such welding operations, the filler wire, which leads a torch, can be resistance-heated by a separate power supply. The wire is fed through a contact tube toward a workpiece and extends beyond the tube. The extension is resistance-heated to aid in the melting of the filler wire. A tungsten electrode may be used to heat and melt the workpiece to form the weld puddle. A power supply provides a large portion of the energy nee-

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ded to resistance-melt the filler wire. In some cases, the wire feed may slip or falter and the current in the wire may cause an arc to occur between the tip of the wire and the workpiece. The extra heat of such an arc may cause burnthrough and spatter resulting in poor weld quality.

[004] Further limitations and disadvantages of conventional, traditional, and proposed approaches will become apparent to one of skill in the art, through comparison of such approaches with embodiments of the present invention as set forth in the remainder of the present application with reference to the drawings.

DESCRIPTION OF THE INVENTION

[005] In order to avoid burn through and/or to improve the weld quality the invention describes a filler wire for use in hot-wire applications according to claim 1, a hot-wire system according to claim 10 and a method of using filler wire in a hot-wire system according to claim 14. Further embodiments of the invention are subject of the sublaims. Embodiments of the present invention comprise a system and method to use at least one filler wire of varying resistance in a system for any of brazing, cladding, building up, filling, hard-facing overlaying, welding, and joining applications. The filler wire has a first section that has a first resistance per unit length. The filler sire also has a second section that has a second resistance per unit length, which is higher than the first resistance per unit length. The second section of the filler wire is configured to melt before the first section during hot-wire applications. In some embodiments, a resistivity of the first section and a resistivity of the second section are equal and the second section has a cross-sectional area

that is smaller than a cross-sectional area of the first section. In some embodiments, a resistivity of filler material in the first section and a resistivity of filler material in the second section are different. The problem according to the application is also solved by a hot-wire system. The system comprises a high intensity heat source that heats at least one workpiece and creates a molten puddle. It further comprises a wire feeder that feeds a filler wire to said molten puddle, and a hot wire power supply operatively connected to said filler wire. The hot wire power supply is supplying a heating current through said filler wire to heat said filler wire. The filler wire comprises a first section that has a first resistance per unit length, and a second section that has a second resistance per unit length which is higher than said first resistance per unit length. The second section is configured to melt before said first section during said hot-wire applications. According to a preferred embodiment of the system a resistivity of filler material in the first section and a resistivity of filler material in the second section are different.

[006] The method also includes applying energy from a high intensity energy source to the workpiece to heat the workpiece at least while using a laser to heat the at least one filler wire. The high intensity energy source may include at least one of a laser device, a plasma arc welding (PAW) device, a gas tungsten arc welding (GTAW) device, a gas metal arc welding (GMAW) device, a flux cored arc welding (FCAW) device, and a submerged arc welding (SAW) device. According to a preferred embodiment of the method according to the invention a resistivity of filler material in the first section and a resistivity of filler material in the second section are different.

[007] These and other features of the claimed invention, as well as details of illustrated embodiments thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[008] The above and/or other aspects of the invention will be more apparent by describing in detail exemplary embodiments of the invention with reference to the accompanying drawings, in which:

[009] FIG. 1 illustrates a functional schematic block diagram of an exemplary embodiment of a combination filler wire feeder and energy source system for any of brazing, cladding, building up, filling, hard-facing overlaying, welding, and joining applications;

[0010] FIGS. 2A-C illustrate exemplary embodiments of filler wires that can be used in the system of Figure 1; and

[0011] FIG. 3 illustrates a functional schematic block diagram of an exemplary embodiment of a combination filler wire feeder and energy source system for any of brazing, cladding, building up, filling, hard-facing overlaying, welding, and joining applications.

DETAILED DESCRIPTION OF THE DRAWINGS

[0012] Exemplary embodiments of the invention will now be described below by reference to the attached Figures. The described exemplary embodiments are intended to assist in the understanding of the invention, and are not intended to limit the scope of the invention in any way. Like reference numerals refer to like elements throughout.

[0013] It is known that welding/joining operations typically join multiple workpieces together in a welding operation where a filler metal is combined with at least some of the workpiece metal to form a joint. Because of the desire to increase production throughput in welding operations, there is a constant need for faster welding operations, which do not result in welds which have a substandard quality. This is also true for cladding/surfacing operations, which use similar technology. It is noted that although much of the following discussions will reference "welding" operations and systems, embodiments of the present invention are not just limited to joining operations, but can similarly be used for cladding, brazing, overlaying, etc. – type operations. Furthermore, there is a need to provide systems that can weld quickly under adverse environmental conditions, such as in remote work sites. As described below, exemplary embodiments of the present invention provide significant advantages over existing welding technologies. Such advantages include, but are not limited to, reduced total heat input resulting in low distortion of the workpiece, very high welding travel speeds, very low spatter rates, welding with the absence of shielding, welding plated or coated materials at high speeds with little or no spatter and welding complex materials at high speeds.

[0014] FIG. 1 illustrates a functional schematic block diagram of an exemplary embodiment of a combination filler wire feeder and energy source system **100** for performing any of brazing, cladding, building up, filling, hard-facing overlaying, and joining/welding applications. The system **100** includes a high energy heat source capable of heating the workpiece **115** to form a weld puddle **145**. The high energy heat source can be a laser subsystem **130/120** that includes a laser device **120** and a weld puddle laser power supply **130** operatively connected to each other. The laser **120** is capable of focusing a laser beam **110** onto the workpiece **115** and the power supply **130** provides the power to operate the laser device **120**. The laser subsystem **130/120** can be any type of high energy laser source, including but not limited to carbon dioxide, Nd:YAG, Yb-disk, YB-fiber, fiber delivered, or direct diode laser systems. Further, even white light or quartz laser type systems can be used if they have sufficient energy. For example, a high intensity energy source can provide at least 500 W/cm^2.

[0015] The following specification will repeatedly refer to the laser subsystem **130/120**, beam **110** and weld puddle laser power supply **130**, however, it should be understood that this reference is exemplary as any high intensity energy source may be used. For example, other embodiments of the high energy heat source may include at least one of an electron beam, a plasma arc welding subsystem, a gas tungsten arc welding subsystem, a gas metal arc welding subsystem, a flux cored arc welding subsystem, and a submerged arc welding subsystem. It should be noted that the high intensity energy sources, such as the laser device **120** discussed herein, should be of a type having sufficient power to provide the necessary energy density for the desired welding operation. That is, the laser device **120** should have a power sufficient to create and maintain a stable weld puddle throughout the welding process, and also reach the desired weld penetration. For example, for some applications, lasers should have the ability to "keyhole" the workpieces being welded. This means that the laser should have sufficient power to fully penetrate the workpiece, while maintaining that level of penetration as the laser travels along the workpiece. Exemplary lasers should have power capabilities in the range of 1 to 20kW, and may have a power capability in the range of 5 to 20kW. Higher power lasers can be utilized, but can become very costly.

[0016] The system **100** also includes a hot filler wire feeder subsystem capable of providing at least one resistive filler wire **140** to make contact with the workpiece **115** in the vicinity of the laser beam **110**. Of course, it is understood that by reference to the workpiece **115** herein, the molten puddle, i.e., weld puddle **145**, is considered part of the workpiece **115**, thus reference to contact with the workpiece **115** includes contact with the puddle **145**. The hot filler wire feeder subsystem includes a filler wire feeder **150**, a contact tube **160**, and a hot wire power supply **170**. During operation, the filler wire **140** is resistance-heated by an electrical current from the hot wire welding power supply **170**, which is operatively connected between the contact tube **160** and the workpiece **115**. Prior to its entry into the weld puddle **145** on the workpiece **115**, the extended portion of the filler wire **140** is heated by the current from the power supply **170** such that the wire **140** approaches or reaches its melting point before contacting the weld puddle **145**. Unlike most welding processes, the present invention melts the filler wire **140** into the weld puddle **145** rather than using a welding arc to transfer the filler wire **140** into the weld puddle **145**. Because the filler wire **140** is heated to at or near its melting point, its presence in the weld puddle **145** will not appreciably cool or solidify the puddle **145** and the wire **140** is quickly consumed into the weld puddle **145**.

[0017] In accordance with an embodiment of the present invention, the hot wire welding power supply **170** is a pulsed direct current (DC) power supply, although alternating current (AC) or other types of power supplies are possible as well. The wire **140** is fed from the filler wire feeder **150** through the contact tube **160** toward the workpiece **115** and extends beyond the tube **160**. The extension portion of the wire **140** is resistance-heated such that the extension portion approaches or reaches the melting point before contacting the weld puddle **145** on the workpiece **115**. The laser beam **110** serves to melt some of the base metal of the workpiece **115** to form the weld puddle **145** and may also help melt the wire **140** onto the workpiece **115**. The power supply **170** provides a large portion of the energy needed to resistance-melt the filler wire **140**.

[0018] Because no welding arc is needed to transfer the filler wire **140** in the process described herein, the feeder subsystem **150** may be capable of simultaneously providing one or more wires, in accordance with certain other embodiments of the present invention. For example, a first wire may be used for hard-facing and/or providing corrosion resistance to the workpiece, and a second wire may be used to add structure to the workpiece. In addition, by directing more than one filler wire to any one weld puddle, the overall deposition rate of the weld process can be significantly increased without a significant increase in heat input. Thus, it is contemplated that open root weld joints can be filled in a single weld pass.

[0019] Of course, the melting temperature of the filler wire **140** will vary depending on the size and chemistry of the wire **140**. Accordingly, the desired temperature of the filler wire during welding will vary depending on the wire **140**. The desired operating temperature for the filler wire **140** can be a data input into the welding system so that the desired wire temperature is maintained during welding. In any event, the temperature of the wire **140** should be such that the wire **140** is consumed into the weld puddle **145** during the welding operation.

[0020] As discussed above, the filler wire **140** is melted into the weld puddle **145** without an arc. Traditionally, the filler wire has a constant cross-sectional area over the length of the wire. This allows for uniform heating of the extension portion of wire **140** prior to its entry into the weld puddle **145**. However, an arc may inadvertently form if filler wire **140** loses contact with the weld puddle **145** due to overheating or if the wire feed **150** slips or falters as it feeds wire **140** to the weld puddle **140**. Such arcs are detrimental to welding process as it may adversely affect weld quality due to burnthrough and splatter. Typically, control units with complicated algorithms are used to predict and control the current through the filler wire **140** in order to prevent such loss of contact. The present invention, however, uses filler wire of varying resistance to prevent (or least minimize) arcing between the wire **140** and workpiece **115**. Nevertheless, some embodiments of the present invention can be used in combination with such prediction and control algorithms. Application no. 13/212,025, titled "Method And System To Start And Use Combination Filler Wire Feed And High Intensity Energy Source For Welding" and incorporated by reference in its entirety, provides exemplary prediction and control algorithms that may be incorporated in sensing and control unit **195** for sensing when the wire **140** is about to lose contact with the workpiece **115**.

[0021] By varying the resistance of filler wire **140**, certain portions of wire **140** will heat faster than other portions when the heating current from power supply **170** begins to flow through the wire **140**. Figure 2A illustrates an embodiment of a filler wire **140A** that can be used in the system of Figure 1. Filler wire **140A** provides the filler material for the welding process and may be coated with (or include materials) such as flux. The filler wire **140A** has a varying outer diameter that ranges from a maximum of $\mathbf{D_1}$ to a minimum of $\mathbf{D_2}$. Thus, the cross-sectional area of filler wire **140A** will vary from a maximum value at $\mathbf{D_1}$ to a minimum value at $\mathbf{D_2}$. The diameter $\mathbf{D_1}$ can be in a range, e.g., between 0.030 to 0.095 in. That is, the diameter $\mathbf{D_1}$ can be a standard filler wire diameter, e.g., 0.030 in, 0.045 in, 0.052 in, 0.063 in, 0.068 in, etc (1 in is approximately 2,54 cm). Of course, filler wire **140A** can have other diameters based on filler wire properties and the welding system. As discussed further below, diameter $\mathbf{D_2}$ will depend on the desired power level for melting filler wire **140A** at location $\mathbf{D_2}$.

[0022] Assuming a resistivity (ρ) for the filler material, the resistance (R) for any given length (l) along wire 140 is $R = (\rho * l)/A$, where A is the cross-sectional area (i.e., $A = \pi/4 * D^2$). From this equation, one can see that the resistance (R) is inversely proportional to the cross-sectional area and proportional to the length (l). That is, for a given length (l) of the filler wire **140A**, the resistance will increase as the cross-sectional area decreases, and for a given cross-sectional area (A), the resistance (R) will increase as length (l) increases. Accordingly, at location $\mathbf{D_1}$ on wire **140A**, the resistance $R_1 = (\rho * l)/(\pi/4 * D_1^2)$; and at location $\mathbf{D_2}$ on wire 140A, the resistance $R_2 = (\rho * l)/(\pi/4 * D_2^2)$.

[0023] Therefore, if the resistivity (ρ) of the filler material is assumed to be uniform, the resistance per unit length of the filler wire **140A** will be at its minimum at diameter D_1 and increase to its maximum at diameter $\mathbf{D_2}$. Because the resistance per unit length of the filler wire **140A** is at its highest at diameter $\mathbf{D_2}$, the resistance heating of filler wire **140A** will melt at that location first due to the resistive heating current flowing through the wire **140A**. In exemplary embodiments, the diameter $\mathbf{D_2}$ is selected such that the filler wire **140A** will melt at location $\mathbf{D_2}$ at a power that is 75-95% of the power value needed to melt the filler wire **140A** at location $\mathbf{D_1}$. Of course, in determining the diameter $\mathbf{D_2}$, the change in resistance of filler wire **140** due to temperature (because of the heating current) may need to be taken into account.

[0024] Thus, during the welding process, power supply **170** will only need to supply 75-95% of the power typically needed for the standard filler wire to melt the filler wire **140** at the location $\mathbf{D_2}$ and for a small amount of filler material, i.e., filler section **142**, to go into the weld puddle **145**. Because filler section **142** melts off into the weld puddle **145** at a reduced power level, the likelihood of creating an arc between filler wire **140A** and workpiece **115** is reduced. In some embodiments, at least a portion of the filler section **142** can be solid as it enters the weld puddle **145** before the weld puddle **145** melts and absorbs the filler section **142**.

[0025] In some exemplary embodiments, the laser device **120** can facilitate the melting of the filler section **142** because laser **120** allows for precise control of the weld puddle **145**, including easy adjustments of the size and depth of the weld puddle **145**. These adjustments are possible because the laser beam **110** can be focused/de-focused easily or have its beam intensity changed very easily. Because of these abilities, the heat distribution on the workpiece **115** can be precisely controlled. This control allows for the creation of a weld puddle **145** that can accept an un-melted (or partially melted) filler section **142** and melt it. In exemplary embodiments of the present invention, the shape and/or intensity of the beam **110** can be adjusted/changed during the welding process to ensure the weld puddle **145** completely melts the filler section **142**. For example, during the welding process, it may be necessary to change the depth of penetration or to change the size of the weld bead in order to melt the filler section **142**. In such embodiments, the shape, intensity, and/or size of the beam **110** can be adjusted during the welding process to provide the needed change in the welding parameters.

[0026] As described above, the filler section **142** impacts the same weld puddle **145** as the laser beam **110**. In some exemplary embodiments, the filler section **142** can impact the same weld puddle remotely from the laser beam **110**. However, in other exemplary embodiments, the filler section **142** impacts the weld puddle **145** at the same location as the laser beam **110**. In such embodiments, the laser beam **110** itself can be used to aid in the melting of filler section **142**. However, because many filler wires are made of materials which can be reflective, if a reflective laser type is used the wire should be heated to a temperature such that its surface reflectivity is reduced, allowing the beam **110** to contribute to the heating/melting of the filler section **142**. In exemplary embodiments of this configuration, the filler section **142** and beam **110** intersect at the point at which the filler section **142** enters the puddle **145**.

[0027] For any given filler wire diameter, the size of the filler section **142** will be determined by the length **L**, which is the distance between locations $\mathbf{D_2}$. Accordingly, along with parameters such as wire speed, the length **L** will aid in determining the rate of deposit of the filler material during the operation. The length **L** of the filler section **142** may be determined based on factors such as the type of filler material, the type of welding to be performed, and the temperature of the weld puddle **145** – to name just a few. For example, in some exemplary embodiments, the length **L** is at least as long as the diameter $\mathbf{D_1}$. In further exemplary embodiments, the length **L** is in the range of -25 to +25% of the diameter $\mathbf{D_1}$. The ranges of length **L** in relation to diameter $\mathbf{D_1}$ are based on resistance of the filler sections at room temperature. In an exemplary embodiment, the filler wire **140A** may be manufactured by crimping the circumference of a standard filler wire to achieve diameter $\mathbf{D_2}$. In some embodiments, the filler wire **140A** may be pre-crimped at the factory. In other embodiments, the filler wire **140A** is crimped by, for example wire feeder **150**, as wire **140A** is being fed to weld puddle **145**. That is, the wire feeder **150** (or some other mechanical device) crimps the wire **140** as it is fed to the operation. Such devices can use a compressive force to crimp the wire **140** as desired. In such an embodiment, the length L can be a user input to sensing and control unit **195** (see Figure 1), which can control wire feeder **150** and the crimping operation consistent with the input data. Alternatively, in other exemplary embodiments the length **L** can be automatically adjusted by sensing and control unit **195** based on welding conditions. For example, the wire feeder **150** can contain a torque sensor (or something similar) which senses that the wire **140** is contacting the bottom of the weld puddle and based on feedback from this sensor the length **L** and/or the heating current can be changed to ensure proper operation and melting of the wire **140** in the puddle. Of course, these functions (i.e., the user input and automated control of length **L**) may be incorporated into wire feeder **150** or other suitable components.

[0028] In the above embodiments, the filler wire **140A** has a circular cross-sectional area that varies from $\mathbf{D_1}$ and $\mathbf{D_2}$. However, the present invention is not limited to just this geometry. For example, in Figure 2B, the filler wire **140B** is formed by notching the filler wire **140B** on opposite sides of the wire **140**. Of course, the present invention is not limited by the shape of the cross-section of the filler wire **140** and any number of different cross-sectional shapes can be used as long as there is a variation in the cross-sectional areas in the filler wire. It is this variation in cross-sectional area which changes the resistivity between the sections. Further, although the filler section **142** is illustrated as approximating a sphere in Figure 2A, the shape of the filler section **142** is not limiting. For example, in Figure 2B, the filler section **142** is illustrated as approximating a cylinder with a diameter of approximately $\mathbf{D_1}$ along filler section **142**. However, in general, filler shapes that optimize the melting of the section **142** in the weld puddle **145** are desired. As in the above embodiments, the filler wire **140B** may be pre-notched at the factory or by wire feeder **150** (or similar components) during the welding process.

[0029] In the above embodiments, the variation in resistance in filler wires **140A** and **140B** is accomplished by changing the cross-section of the filler wire **140**. However, the present invention is not limited to just changing the cross-sectional areas. In some exemplary embodiments of the present invention, the cross-section of the filler wire may remain constant and the resistivity is varied by changing the density of the filler materials in the filler wire **140C** as illustrated in Figure 2C. In Figure 2C, filler material in portion **10** of filler wire **140C** has a higher resistivity (ohm-meter) (for example, due to a lower density) than in portion **20**. Thus, for a given cross-sectional area and filler material, portion **10** will have a higher resistance per unit length and will melt faster than portion **20**. Alternatively, or in addition to, the filler material in portion **10** can be of a different material composition (and resistivity) than in portion **20**. Thus, embodiments of the present invention can use a wire **140** having various densities, construction, shape, and/or material composition along its length which varies the resistivity of the wire **140** along its length. Such a construction allows for the use of a lower heating current which can aid in avoiding the creation of a welding arc.

[0030] In exemplary embodiments of the present invention, the portions **142** have a resistance per unit length that is in the range of 5 to 45% lower than that of portions D_2,**10**. In other exemplary embodiments, the difference is in the range of 5 to 25%. The above ranges are based on resistance values of the filler sections at room temperature.

[0031] In the above exemplary embodiments, the filler wire is assumed to be solid. However, the same principles apply to a cored filler wire (metal or flux cored), or flux coated wires. In fact, embodiments of the present invention can use the flux (either cored or coated flux) to vary the resistance of the wire **140**. That is, the present invention includes embodiments where a solid wire core or sheath is used having consistent properties – consistent with arc welding consumables, where the shape, geometry and/or chemistry of a flux secured to selected portions of the metal part of the wire **140** changes the resistance of the wire **140** at those portions.

[0032] Figure 3 depicts yet another exemplary embodiment of the present invention. Figure 3 shows an embodiment similar to that as shown in Figure 1. However, certain components and connections are not depicted for clarity. Figure 3 depicts a system **1400** in which a thermal sensor **1410** is utilized to monitor the temperature of the wire **140**. The resistance of filler wire **140** varies as discussed above and, in some embodiments, can be any one of the filler wires **140A**, **140B**, and **140C**. The thermal sensor **1410** can be of any known type capable of detecting the temperature of the wire **140**. The sensor **1410** can make contact with the wire **140** or can be coupled to the tip **160** so as to detect the temperature of the wire. In a further exemplary embodiment of the present invention, the sensor **1410** is a type which uses a laser or infrared beam which is capable of detecting the temperature of a small object – such as the diameter of a filler wire – without contacting the wire **140**. In such an embodiment the sensor **1410** is positioned such that the temperature of the wire **140** can be detected at the stick out of the wire **140** – that is at some point between the end of the tip of contact tube **160** and the weld puddle **145**. The sensor **1410** should also be positioned such that the sensor **1410** for the wire **140** does not sense the temperature of weld puddle **145**.

[0033] The sensor **1410** is coupled to a sensing and control unit **195** such that temperature feed back information can be provided to the power supply **170**, the laser power supply **130**, and/or wire feeder **150** so that the control of the system **1400** can be optimized. For example, the power or current output of the power supply **170** can be adjusted based on at least the feedback from the sensor **1410**. That is, in an embodiment of the present invention either the user can input a desired temperature setting (for a given weld and/or wire **140**) or the sensing and control unit **195** can set a desired temperature based on other user input data (filler wire diameter, minimum cross-sectional area of the filler wire, resistivity of filler material, length **L** of filler droplet, wire feed speed, electrode type, etc.) and then the sensing and control unit **195** would control at least the power supply **170**, laser power supply **130**, and/or wire feeder **150** to maintain that desired temperature.

[0034] In such an embodiment it is possible to account for heating of the wire **140** that may occur due to the laser beam **110** impacting on the wire **140** before the wire **140** enters the weld puddle **145**. In embodiments of the invention the temperature of the wire **140** can be controlled only via power supply **170** by controlling the current in the wire **140**. However, in other embodiments at least some of the heating of the wire **140** can come from the laser beam **110** impinging on at least a part of the wire **140**. As such, the current or power from the power supply **170** alone may not be representative of the temperature of the wire **140**. As such, utilization of the sensor **1410** can aid in regulating the temperature of the wire **140** through control of the power supply **170**, the laser power supply **130** and/or wire feeder **150**.

[0035] In a further exemplary embodiment (also shown in Figure 3) a temperature sensor **1420** is directed to sense the temperature of the weld puddle **145**. In this embodiment the temperature of the weld puddle **145** is also coupled to the sensing and control unit **195**. However, in another exemplary embodiment, the sensor **1420** can be coupled directly to the laser power supply **130** and/or wire feeder **150**. Feedback from the sensor **1420** can be used to control output from laser power supply **130**/laser **120**. That is, the energy density of the laser beam **110** can be modified to ensure that the desired weld puddle temperature is achieved. The sensor **1420** may also be used to control wire feeder **150**. For example, the length of filler droplet **142** (see Figs. 2A and 2B) may be controlled based on the temperature of weld puddle **145**.

[0036] In another exemplary embodiment of the present invention, the sensing and control unit **195** can be coupled to a feed force detection unit (not shown) which is coupled to the wire feeder **150**. The feed force detection units are known and detect the feed force being applied to the wire **140** as it is being fed to the workpiece **115**. For example, such a detection unit can monitor the torque being applied by a wire feeding motor in the wire feeder **150**. If the wire **140** passes through the molten weld puddle **145** without fully melting it will contact a solid portion of the workpiece **115** and such contact will cause the feed force to increase as the motor is trying to maintain a set feed rate. This increase in force/torque can be detected and relayed to the control unit **195** which utilizes this information to adjust the heating current from power supply **170** to the wire **140** to ensure proper melting of the wire **140** in the weld puddle **145**. This information can also be used to change the length L to the extent any shaping of the wire is conducted during the operation.

[0037] In Figures 1 and 3 the laser power supply **130**, hot wire power supply 170, wire feeder **150**, and sensing and control unit **195** are shown separately for clarity. However, in embodiments of the invention these components can be made integral into a single welding system. Aspects of the present invention do not require the individually discussed components above to be maintained as separately physical units or stand alone structures.

[0038] While the invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

REFERENCE NUMBERS

10	portion	145	weld puddle
20	portion	150	wire feeder
100	system	160	contact tube
110	beam	170	(welding) power supply
115	workpiece	195	sensing/control unit
120	laser	1400	system
130	power supply	1410	thermal sensor
140	filler wire	1420	temperatur sensor
140A	filler wire	D_1	diameter
140B	filler wire	D_2	diameter
140C	filler wire	I, L	length
142	filler section		

CLAIMS

1. A filler wire (140, 140A, 140B, 140C) for use in hot-wire applications, said filler wire (140, 140A, 140B, 140C) comprising:
   a first section that has a first resistance per unit length; and
   a second section that has a second resistance per unit length which is higher than said first resistance per unit length,
   wherein said second section is configured to melt before said first section during said hot-wire applications.

2. The filler wire (140, 140A, 140B, 140C) of claim 1, wherein a resistivity of said first section and a resistivity of said second section are equal, and wherein said second section has a cross-sectional area that is smaller than a cross-sectional area of said first section.

3. The filler wire (140, 140A, 140B, 140C) of claim 1 or 2, wherein said second section melts at a power level that is 75% to 95% of a power level required to melt said first section, and/or wherein a length (L) of said first section is in a range of -25% to +25% of a diameter of said first section, and/or wherein a resistance per unit length of said first section is in a range of 5% to 45% of a resistance per unit length of said second section.

4. The filler wire (140, 140A, 140B, 140C) of any of the claims 1 to 3, wherein a resistivity of filler material in said first section and a resistivity of filler material in said second section are different.

5. The filler wire (140, 140A, 140B, 140C) of any of the claims 1 to 4, wherein a cross-section area of said second section and a cross-sectional area of said first section are equal.

6. The filler wire (140, 140A, 140B, 140C) of any of the claims 1 to 5, wherein a density of said filler material in said second section and a density of said filler material in said first section are different.

7. The filler wire (140, 140A, 140B, 140C) of any of the claims 1 to 6, wherein a material composition of said filler material in said second section and a material composition of said filler material in said first section are different.

8. The filler wire (140, 140A, 140B, 140C) of any of the claims 1 to 7, wherein said second section melts at a power level that is 75% to 95% of a power level required to melt said first section.

9. The filler wire (140, 140A, 140B, 140C) of any of the claims 1 to 8, wherein a resistance per unit length of said first section is in a range of 5% to 45% of a resistance per unit length of said second section.

10. A hot-wire system (100) , said system (100) comprising:

a high intensity heat source that heats at least one workpiece (115) and creates a molten puddle (145);

a wire feeder that feeds a filler wire (140, 140A, 140B, 140C) to said molten puddle;

a hot wire power supply (170) operatively connected to said filler wire (140, 140A, 140B, 140C), said hot wire power supply (170) supplying a heating current through said filler wire (140, 140A, 140B, 140C) to heat said filler wire (140, 140A, 140B, 140C),

wherein said filler wire (140, 140A, 140B, 140C) comprises,

a first section that has a first resistance per unit length, and

a second section that has a second resistance per unit length which is higher than said first resistance per unit length,

wherein said second section is configured to melt before said first section during said hot-wire applications.

11. The hot wire system (100) of claim 10, wherein at least a portion (10, 20) of said first section is solid as said first section enters said molten puddle (145), and

wherein said molten puddle (145) melts and absorbs said portion (10, 20) of said first section.

12. The hot wire system (100) of claim 10 or 11, wherein a resistivity of said first section and a resistivity of said second section are equal, and

wherein said second section has a cross-sectional area that is smaller than a cross-sectional area of said first section.

13. The hot wire system (100) of any of the claims 10 to 12, wherein said heating current melts said second section at a power level that is 75% to 95% of a power level required to melt said first section.

14. A method of using filler wire in a hot-wire system, said method comprising:

heating at least one workpiece to a molten puddle;

feeding a filler wire to said molten puddle;

supplying a heating current to said hot wire power supply to heat said filler wire,

wherein said filler wire comprises,

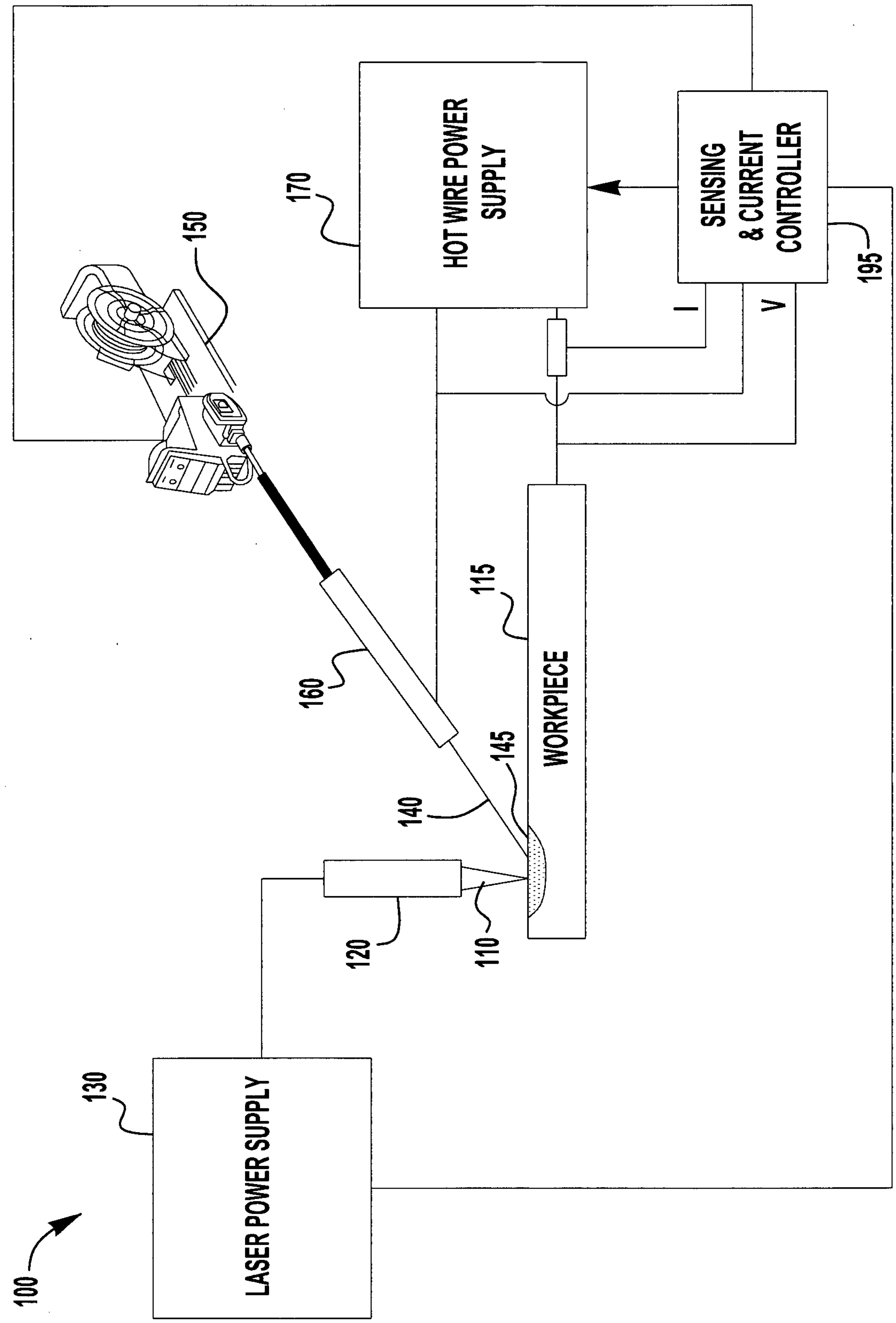
a first section that has a first resistance per unit length, and

a second section that has a second resistance per unit length which is higher than said first resistance per unit length,

wherein said second section is configured to melt before said first section during said hot-wire applications.

15. The method of claim 18, wherein a resistivity of said first section and a resistivity of said second section are equal, and

wherein said second section has a cross-sectional area that is smaller than a cross-sectional area of said first section.



HOT WIRE POWER SUPPLY
SENSING & CURRENT CONTROLLER
I
V
WORKPIECE
LASER POWER SUPPLY
100
110
115
120
130
140
145
150
160
170
195

FIG. 1

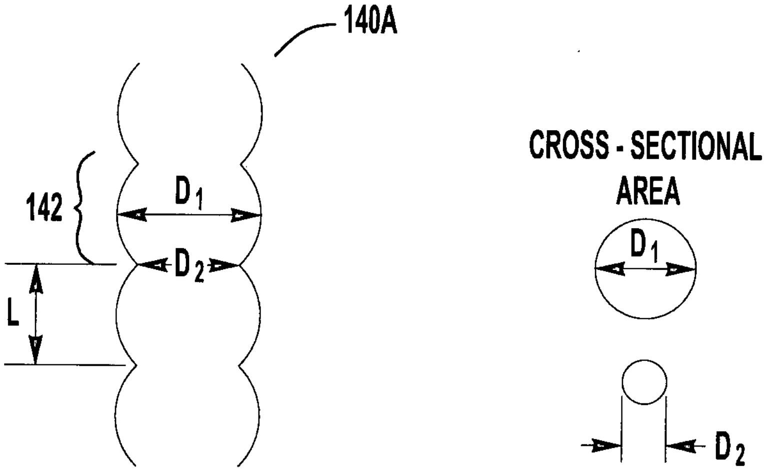


FIG. 2A

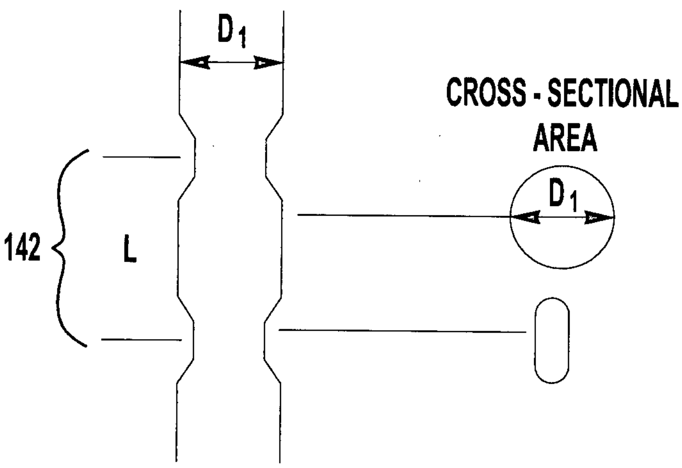


FIG. 2B

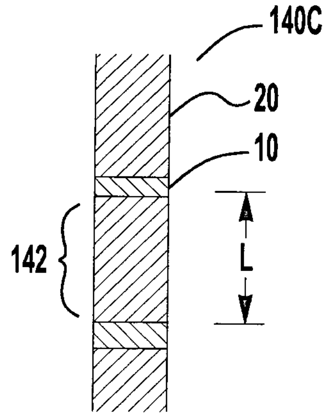


FIG. 2C

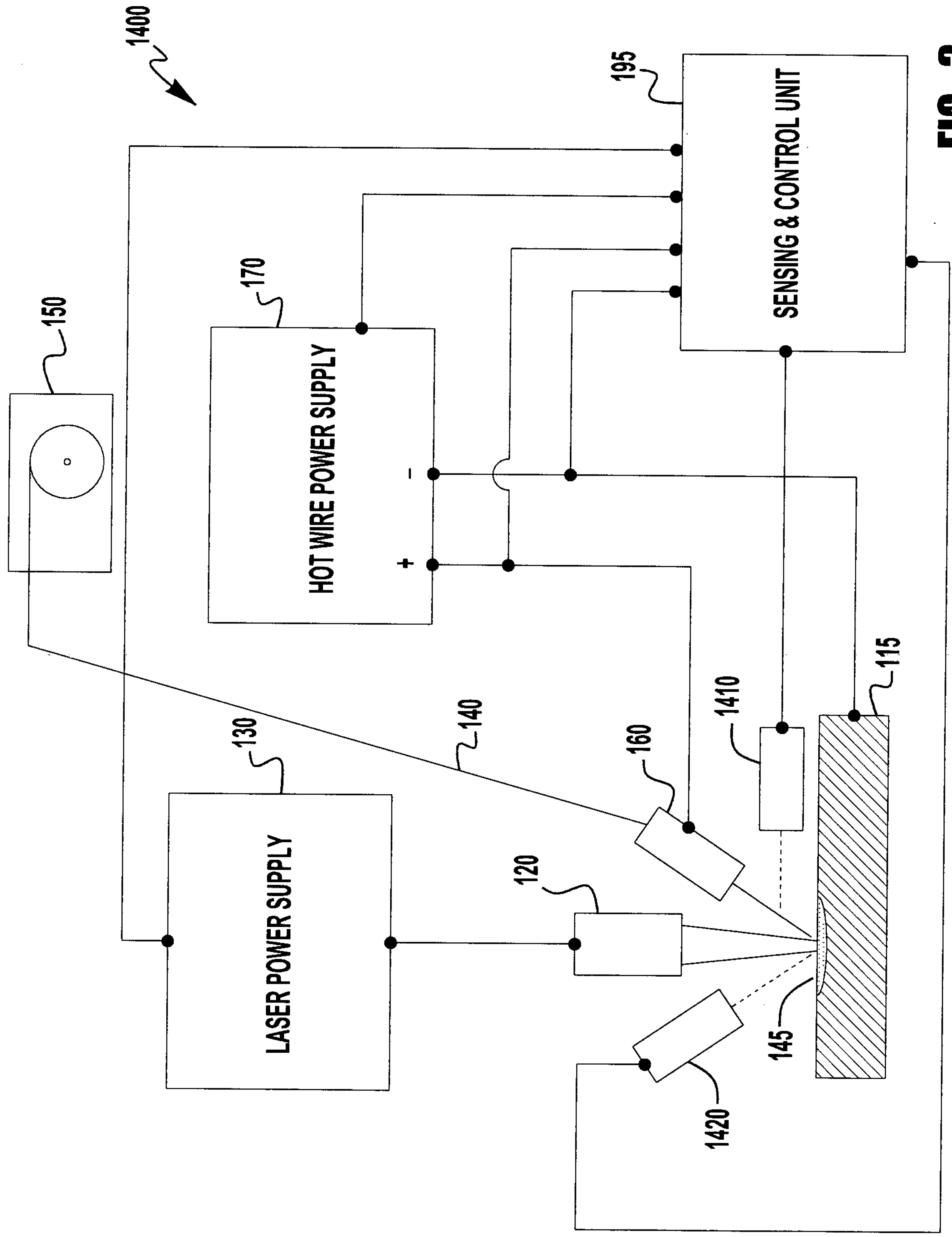

1400
150
170
195
HOT WIRE POWER SUPPLY
SENSING & CONTROL UNIT
LASER POWER SUPPLY
130
140
160
1410
115
120
145
1420
+
-

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/001459

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23K35/02 B23K9/10 B23K9/24
ADD.

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)
B23K

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

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

EPO-Internal, WPI Data

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X	US 6 137 081 A (BLANKENSHIP GEORGE D [US] ET AL) 24 October 2000 (2000-10-24) column 1, lines 25-37 column 2, line 14 - column 10, line 65 figures 1-11 -----	1-15
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"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)

"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

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 November 2013	05/12/2013

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/001459

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	paragraphs [0001], [0025], [0026], [0029], [0052], [0053] figures 1,7	1-9
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International application No
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