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Systems and methods to control a wire electrode at the end of a weld

Abstract

Systems and methods are described to address issues associated with welding with cored wires. In certain processes, a welding wire may “stick” or fuse to a contact tip, such as at termination of a weld. To mitigate the negative effects of a wire fusing to a contact tip, the wire remains in motion at a time prior to the end of the weld, as the weld ends, and/or for a time after the end of the weld, to limit and/or eliminate fusion between the wire and the contact tip.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application hereby claims priority to and the benefit of U.S. Provisional Application Ser. No. 63/085,726 entitled “Systems And Methods To Control A Wire Electrode At The End Of A Weld,” filed Sep. 30, 2020. The above listed U.S. Application is hereby incorporated by reference in its entirety for all purposes.

BACKGROUND

(1) One of the first steps of a welding process is establishing an electrical arc between a welding torch and a workpiece. Some arc welding systems use wire electrodes fed to the welding torch to establish the electrical arc. Establishing the electrical arc with the wire electrode is easier if the wire electrode is free of welding residue adhered or unwanted contact at initiation of the weld. For example, at the end of some welding processes, the wire electrode may “stick” or fuse to a contact

tip, creating issues at initiation of the next weld.
(2) Limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with the present disclosure as set forth in the remainder of the present application with reference to the drawings.

BRIEF SUMMARY

(3) The present disclosure is directed to systems and methods for mitigating the negative effects of a wire fusing to a contact tip at an end of a weld, substantially as illustrated by and/or described in connection with at least one of the figures, and as set forth more completely in the claims.
(4) These and other advantages, aspects and novel features of the present disclosure, as well as details of an illustrated example thereof, will be more fully understood from the following description and drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a perspective view of an operator using an example welding system, in accordance with aspects of this disclosure.
(2) FIG. **2** is a block diagram illustrating components of the example welding system of FIG. **1**, in accordance with aspects of this disclosure.
(3) FIG. **3** is a flowchart illustrating an example welding program, in accordance with aspects of this disclosure.
(4) FIGS. **4***a* and **4***b* are perspective views illustrating an example welding process, in accordance with aspects of this disclosure.
(5) The figures are not necessarily to scale. Where appropriate, the same or similar reference numerals are used in the figures to refer to similar or identical elements.

DETAILED DESCRIPTION

(6) Systems and methods for mitigating the negative effects of a wire fusing to a contact tip at an end of a weld are disclosed. In particular, the disclosed systems and methods address issues associated with welding with cored wires, although the principles may be applicable for a variety of wire types or welding processes where wire “sticking” issues exist (e.g., wire materials with a low melting point and high surface resistance; copper coated solid wires; aluminum wires, stainless steel; etc.). For example, in certain processes, a welding wire may “stick” or fuse to a contact tip, such as at termination of a weld. To mitigate the negative effects of a wire fusing to a contact tip, the wire remains in motion at a time prior to the end of the weld, as the weld ends, and/or for a time after the end of the weld, to limit and/or eliminate fusion between the wire and the contact tip.
(7) In some examples, upon determination of the end of a weld (or that the end of the weld is imminent), a wire feeder retracts the wire away from the weld (e.g., by a predetermined time and/or a predetermined distance). In some examples, even as the system has determined an end of the weld (or an end is imminent), current may continue to flow through the wire (e.g., to burn the wire, clear a weld puddle, etc.), even as the wire is retracted. Movement of the wire at this point in the welding process reduces the amount of time any part of the wire (e.g., a heated tip of the wire) is in contact with the contact tip, thereby reducing the chance for fusion. Once the wire has retracted for a given time period or for a given distance, the wire feeder advances the wire in preparation for another weld, thereby reducing the amount of lull time between welds while still limiting the occurrence of a fusion event.
(8) Cored wire, also referred to as metal-cored wire, employs an external sheath to encase powdered metals. The sheath makes electrical contact with a contact tip of a welding torch, through which a substantial amount of current flows from the contact tip to a workpiece to form a weld. For instance, welding currents can range from below 350 to over 550 Amps. Although the contact tip

has a relatively large surface area, the point of contact with the wire is relatively small (e.g., with an area of 0.2 mm.sup.2 or less). The transfer of high current and energy tends to generate a hot spot on the wire. For example, the hot spot can, and often does, freeze and/or solidify (e.g., fuse), creating a spot weld inside the contact tip and causing the wire to temporarily stop feeding.
(9) The wire may eventually break free from the contact tip (e.g., in response to a force from a wire feeder to drive the wire). For instance, the feeder may be continuously feeding the wire until the push force is able to break the fusion point between the wire and the contact tip. However, by the time the spot weld breaks freeing up the wire, a large spring force has been built-up in the wire, which may cause the wire to rapidly advance from the contact tip at a wire feed rate several times greater than a commanded wire feed rate. As a result, the wire is thrust into the weld puddle causing a hard short. Further, in order to clear the hard short created at the weld puddle, additional current must be added, creating another hot spot, which further exacerbates the situation.
(10) In some examples, the end of a weld typically involves some slowdown of the wire feed speed prior to application of an increased current. For example, a greater current is used to “burn” the wire, which provides some distance between the end of the weld wire and the weld puddle. This is done to prevent the wire from solidifying in the weld puddle at the end of the weld. Unfortunately, burn back can result, causing a hot spot on the wire that, when stopping the wire, increases the possibility for the hot spot to fuse (or freeze) to the contact tip. When the system initiates another weld, the fused portion of the wire creates a violent and unpredictable weld start, which may include wire stubbing, “flaming baton”, burn back, or a bead hump. To address the issue of a sticking wire, other attempts focused on reducing energy at the time of the weld stop. However, energy at too low of a level results in a ball of metal being left on the end of the wire or the wire freezing in the puddle.
(11) Disclosed systems and methods address these problems by moving the wire at the end of a weld to ensure any hot spot does not fuse within the contact tip. In some examples, the wire is retracted during the stopping point of the weld, and then the wire is advanced forward to ensure the wire is in a position to immediately perform the next weld. For instance, retracting the wire creates distance between the end of the wire and the workpiece. The wire advances in preparation for the next weld start to ensure there is no delay. This is particularly applicable for cyclical weld programs and/or welding of multiple welds in rapid succession, such as industrial welding by robotic welders (e.g., automotive applications employing stitch welding).
(12) In disclosed examples, a welding system includes a wire feeder to advance and/or retract a welding wire; a welding power supply to provide power to a welding torch for establishing an electrical arc between the welding wire and a workpiece to perform a weld; and control circuitry configured to: determine an end of the weld and prior to initiation of another weld; control the wire feeder to retract the welding wire for a first time or for a first distance in response to a determination the weld has ended; and control the wire feeder to advance the welding wire for a second time or for a second distance.
(13) In some examples, the end of the weld corresponds to one of completion of the weld or a determination that the end of the weld is imminent. In some examples, determination of the end of the weld is based at least in part on data from a predetermined welding program or an input from a sensor. In some examples, the welding program is defined by a welding process to perform a plurality of welds in succession.
(14) In examples, one or more of a length or a duration of the weld is predetermined in accordance with the welding program, the control circuitry further configured to determine the end of a weld based on the predetermined length or the predetermined duration. In examples, the welding program comprises a cyclic pattern of a plurality of similar or different welds. In examples, the sensor input corresponds to a current or a voltage of the power to the welding torch falling within a threshold range of values, or a change in the current or voltage falling within a threshold range of values.

(15) In some examples, the control circuitry is further configured to control the welding power supply to provide power to the welding torch to initiate another weld after the second time or the second distance has been achieved.
(16) In some examples, upon determining that the end of the weld is imminent, the control circuitry is further configured to control the power supply to provide current to the welding torch as the welding wire retracts. In some examples, upon determining that the end of the weld is imminent, the control circuitry is further configured to control the power supply to end provision of power to the welding torch.
(17) In disclosed examples, a wire feed system includes a drive mechanism configured to advance and/or retract a welding wire for establishing an electrical arc between the welding wire and a workpiece to perform a weld; and control circuitry configured to: receive a signal corresponding to an end of the weld; control the drive mechanism to retract the welding wire for a first time or for a first distance; and control the drive mechanism to advance the welding wire for a second time or for a second distance prior to initiation of another weld.
(18) In some examples, the first time is equivalent to the second time or the first distance is equivalent to the second distance. In some examples, the first time is greater than the second time or the first distance is greater than the second distance.
(19) In some examples, determination of the end of the weld is based at least in part on data from a predetermined welding program or an input from a sensor, the sensor input corresponding to a change in current powering a motor of the drive mechanism.
(20) In some examples, the welding wire is a cored wire. In examples, the cored wire comprises a metallic sheath enclosing a powdered metal. In examples, the welding wire comprises a metallic solid wire.
(21) In some examples, the control circuitry is further configured to initiate another weld after the second time. In examples, the wire feed system comprises a wire feeder configured to feed a welding wire to a welding torch. In examples, the wire feed system comprises a motorized torch with the drive mechanism incorporated within the torch.
(22) In some examples, upon determining that the end of the weld is imminent, the control circuitry is further configured to control the power supply to reduce power to a wire feeder motor for a predetermine time prior to controlling the wire feeder to retract the welding wire.
(23) Several examples are provided with respect to welding power supplies and various accessories. However, the concepts and principles disclosed herein are equally applicable to various power and control systems, including but not limited to engine-driven power systems driving one or more of a generator, an air compressor, and/or a hybrid welding power supply.
(24) As used herein, the terms “first” and “second” may be used to enumerate different components or elements of the same type, and do not necessarily imply any particular order.
(25) The term “welding-type system,” as used herein, includes any device capable of supplying power suitable for welding, plasma cutting, induction heating, Carbon Arc Cutting-Air (e.g., CAC-A), and/or hot wire welding/preheating (including laser welding and laser cladding), including inverters, converters, choppers, resonant power supplies, quasi-resonant power supplies, etc., as well as control circuitry and other ancillary circuitry associated therewith.
(26) As used herein, the term “welding power” or “welding-type power” refers to power suitable for welding, plasma cutting, induction heating, CAC-A and/or hot wire welding/preheating (including laser welding and laser cladding). As used herein, the term “welding-type power supply” and/or “power supply” refers to any device capable of, when power is applied thereto, supplying welding, plasma cutting, induction heating, CAC-A and/or hot wire welding/preheating (including laser welding and laser cladding) power, including but not limited to inverters, converters, resonant power supplies, quasi-resonant power supplies, and the like, as well as control circuitry and other ancillary circuitry associated therewith.
(27) As used herein, the term “torch,” “welding torch,” “welding tool” or “welding-type tool”

refers to a device configured to be manipulated to perform a welding-related task, and can include a hand-held welding torch, robotic welding torch, gun, gouging tool, cutting tool, or other device used to create the welding arc.

(28) As used herein, the term "welding mode," "welding process," "welding-type process" or "welding operation" refers to the type of process or output used, such as current-controlled (CC), voltage-controlled (CV), pulsed, gas metal arc welding (GMAW), flux-cored arc welding (FCAW), gas tungsten arc welding (GTAW, e.g., TIG), shielded metal arc welding (SMAW), spray, short circuit, CAC-A, gouging process, cutting process, and/or any other type of welding process.

(29) As used herein, the term "welding program" or "weld program" includes at least a set of welding parameters for controlling a weld, which may include a weld schedule, operational settings, or others. A welding program may further include other software, algorithms, processes, or other logic to control one or more welding-type devices to perform a weld.

(30) As used herein, "power conversion circuitry" and/or "power conversion circuits" refer to circuitry and/or electrical components that convert electrical power from one or more first forms (e.g., power output by a generator) to one or more second forms having any combination of voltage, current, frequency, and/or response characteristics. The power conversion circuitry may include safety circuitry, output selection circuitry, measurement and/or control circuitry, and/or any other circuits to provide appropriate features.

(31) As used herein, the terms "coupled," "coupled to," and "coupled with," each mean a structural and/or electrical connection, whether attached, affixed, connected, joined, fastened, linked, and/or otherwise secured. As used herein, the term "attach" means to affix, couple, connect, join, fasten, link, and/or otherwise secure. As used herein, the term "connect" means to attach, affix, couple, join, fasten, link, and/or otherwise secure.

(32) As used herein the terms "circuits" and "circuitry" refer to any analog and/or digital components, power and/or control elements, such as a microprocessor, digital signal processor (DSP), software, and the like, discrete and/or integrated components, or portions and/or combinations thereof, including physical electronic components (i.e., hardware) and any software and/or firmware ("code") which may configure the hardware, be executed by the hardware, and or otherwise be associated with the hardware. As used herein, for example, a particular processor and memory may comprise a first "circuit" when executing a first one or more lines of code and may comprise a second "circuit" when executing a second one or more lines of code. As utilized herein, circuitry is "operable" and/or "configured" to perform a function whenever the circuitry comprises the necessary hardware and/or code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled or enabled (e.g., by a user-configurable setting, factory trim, etc.).

(33) The terms "control circuit," "control circuitry," and/or "controller," as used herein, may include digital and/or analog circuitry, discrete and/or integrated circuitry, microprocessors, digital signal processors (DSPs), and/or other logic circuitry, and/or associated software, hardware, and/or firmware. Control circuits or control circuitry may be located on one or more circuit boards that form part or all of a controller, and are used to control a welding process, a device such as a power source or wire feeder, and/or any other type of welding-related system.

(34) As used herein, the term "processor" means processing devices, apparatus, programs, circuits, components, systems, and subsystems, whether implemented in hardware, tangibly embodied software, or both, and whether or not it is programmable. The term "processor" as used herein includes, but is not limited to, one or more computing devices, hardwired circuits, signal-modifying devices and systems, devices and machines for controlling systems, central processing units, programmable devices and systems, field-programmable gate arrays, application-specific integrated circuits, systems on a chip, systems comprising discrete elements and/or circuits, state machines, virtual machines, data processors, processing facilities, and combinations of any of the foregoing. The processor may be, for example, any type of general purpose microprocessor or microcontroller,

a digital signal processing (DSP) processor, an application-specific integrated circuit (ASIC), a graphic processing unit (GPU), a reduced instruction set computer (RISC) processor with an advanced RISC machine (ARM) core, etc. The processor may be coupled to, and/or integrated with a memory device.

(35) As used, herein, the term "memory" and/or "memory device" means computer hardware or circuitry to store information for use by a processor and/or other digital device. The memory and/or memory device can be any suitable type of computer memory or any other type of electronic storage medium, such as, for example, read-only memory (ROM), random access memory (RAM), cache memory, compact disc read-only memory (CDROM), electro-optical memory, magneto-optical memory, programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically-erasable programmable read-only memory (EEPROM), a computer-readable medium, or the like. Memory can include, for example, a non-transitory memory, a non-transitory processor readable medium, a non-transitory computer readable medium, non-volatile memory, dynamic RAM (DRAM), volatile memory, ferroelectric RAM (FRAM), first-in-first-out (FIFO) memory, last-in-first-out (LIFO) memory, stack memory, non-volatile RAM (NVRAM), static RAM (SRAM), a cache, a buffer, a semiconductor memory, a magnetic memory, an optical memory, a flash memory, a flash card, a compact flash card, memory cards, secure digital memory cards, a microcard, a minicard, an expansion card, a smart card, a memory stick, a multimedia card, a picture card, flash storage, a subscriber identity module (SIM) card, a hard drive (HDD), a solid state drive (SSD), etc. The memory can be configured to store code, instructions, applications, software, firmware and/or data, and may be external, internal, or both with respect to the processor **130**.

(36) The term "power" is used throughout this specification for convenience, but also includes related measures such as energy, current, voltage, resistance, conductance, and enthalpy. For example, controlling "power" may involve controlling voltage, current, energy, resistance, conductance, and/or enthalpy, and/or controlling based on "power" may involve controlling based on voltage, current, energy, resistance, conductance, and/or enthalpy.

(37) As used herein, a welding power supply, a welding-type power supply and/or power source refers to any device capable of, when power is applied thereto, supplying welding, cladding, brazing, plasma cutting, induction heating, laser (including laser welding, laser hybrid, and laser cladding), carbon arc cutting or gouging, and/or resistive preheating, including but not limited to transformer-rectifiers, inverters, converters, resonant power supplies, quasi-resonant power supplies, switch-mode power supplies, etc., as well as control circuitry and other ancillary circuitry associated therewith.

(38) Turning now to the figures, FIGS. **1** and **2** show an example perspective and block diagram view, respectively, of a welding system **100**. In the example of FIG. **1**, the welding system **100** includes a welding torch **118** and work clamp **117** coupled to a welding power supply **108** within a welding cell **102**. In the example of FIG. **1**, the welding torch **118** is coupled to the welding power supply **108** via a welding cable **126**, while the clamp **117** is coupled to the welding power supply **108** via a clamp cable **115**. In the example of FIG. **1**, an operator **116** is handling the welding torch **118** near a welding bench **112** that supports a workpiece **110** coupled to the work clamp **117**. While only one workpiece **110** is shown in the examples of FIGS. **1** and **2**, in some examples there may be several workpieces **110**. While a human operator **116** is shown in FIG. **1**, in some examples, the operator **116** may be a robot and/or automated welding machine.

(39) In the example of FIG. **1**, the welding torch **118** is a welding gun configured for gas metal arc welding (GMAW). In some examples, the welding torch **118** may comprise a gun configured for flux-cored arc welding (FCAW). In the examples of FIGS. **1** and **2**, the welding torch **118** includes a trigger **119**. In some examples, the trigger **119** may be activated by the operator **116** to trigger a welding operation (e.g., an arc welding process). In some examples, such as a robotic and/or automated welding process, a welding schedule or welding process may be accessed from a

memory (e.g., memory **224** of FIG. **2**) to automatically initiate one or more welds.

(40) In the example of FIGS. **1** and **2**, the welding power supply **108** includes (and/or is coupled to) a wire feeder **140**. In the example of FIG. **2**, the wire feeder **140** houses a wire spool **214** that is used to provide the welding torch **118** with a wire electrode **250** (e.g., solid wire, cored wire, coated wire, etc.). In the example of FIG. **2**, the wire feeder **140** further includes rollers **218** configured to feed the wire electrode **250** to the torch **118** (e.g., from the spool **214**) and/or retract the wire electrode **250** from the torch **118** (e.g., back to the spool **214**). As shown, the wire feeder **140** further includes a motor **219** (e.g., drive mechanism or similar) configured to turn one or more of the rollers **218**, so as to feed (and/or retract) the wire electrode **250**. In some examples, the welding system **100** may be a push/pull system, and the welding torch **118** may also include one or more rollers **218** and/or motors **219** configured to feed and/or retract the wire electrode **250**. While, in the example of FIG. **2**, the wire electrode **250** is depicted as being fed from the wire feeder **140** to the welding torch **118** in isolation, in some examples the wire electrode **250** may be routed through the welding cable **126** shown in FIG. **1** with other components of the welding system **100** (e.g., gas, power, etc.). In some examples, the welding torch **118** includes a separate wire feeder unit **120** configured to advance and/or retract the wire electrode **250** independently of or in concert with wire feeder **140**. Thus, reference to a wire feeder and/or wire feed system (and/or associated motors, drive rolls and/or drive mechanisms) may include one or both of the wire feeder **140** and wire feeder unit **120**. In some examples, a buffer **121** may be included to allow for retraction of the wire electrode **250** (e.g., via wire feeder unit **120**) at the welding torch **118** without conflicting with a force on the wire electrode **250** from the wire feeder unit **140**.

(41) In the example of FIGS. **1** and **2**, the welding power supply **108** also includes (and/or is coupled to) a gas supply **142**. In the example of FIG. **2**, the gas supply **142** is connected to the welding torch **118** through line **212**. In some examples, the gas supply **142** supplies a shielding gas and/or shielding gas mixtures to the welding torch **118** (e.g., via line **212**). A shielding gas, as used herein, may refer to any gas (e.g., CO.sub.2, argon) or mixture of gases that may be provided to the arc and/or weld pool in order to provide a particular local atmosphere (e.g., shield the arc, improve arc stability, limit the formation of metal oxides, improve wetting of the metal surfaces, alter the chemistry of the weld deposit, and so forth). While depicted as its own line **212** in the example of FIG. **2**, in some examples the line **212** may be incorporated into the welding cable **126** shown in FIG. **1**.

(42) In the example of FIGS. **1** and **2**, the welding power supply **108** also includes an operator interface **144**. In the example of FIG. **1**, the operator interface **144** comprises one or more adjustable inputs (e.g., knobs, buttons, switches, keys, etc.) and/or outputs (e.g., display screens, lights, speakers, etc.) on the welding power supply **108**. In some examples, the operator interface **144** may comprise a remote control and/or pendant. In some examples, the operator **116** may use the operator interface **144** to enter and/or select one or more weld parameters (e.g., voltage, current, gas type, wire feed speed, workpiece material type, filler type, etc.) and/or weld operations for the welding power supply **108**. In some examples, the weld parameters and/or weld operations may be stored in a memory **224** of the welding power supply **108** and/or in some external memory. The welding power supply **108** may then control (e.g., via control circuitry **134**) its operation according to the weld parameters and/or weld operations.

(43) In some examples (e.g., where the operator is a robot and/or automated welding machine), the operator interface **144** may be used to start and/or stop a welding process (e.g., stored in memory **224** and executed via control circuitry **134**). In some examples, the operator interface **144** may further include one or more receptacles configured for connection to (and/or reception of) one or more external memory devices (e.g., floppy disks, compact discs, digital video disc, flash drive, etc.). In the example of FIG. **2**, the operator interface **144** is communicatively coupled to control circuitry **134** of the welding power supply **108**, and may communicate with the control circuitry **134** via this coupling.

(44) In the example of FIGS. **1** and **2**, the welding power supply **108** is configured to receive input power (e.g., from AC mains power, an engine/generator, a solar generator, batteries, fuel cells, etc.), and convert the input power to DC (and/or AC) output power (e.g., welding output power). In the example of FIG. **2**, the input power is indicated by arrow **202**. In the example of FIG. **1**, the output power may be provided to the welding torch **118** via welding cable **126**. In the example of FIG. **2**, the output power may be provided to the welding torch **118** via line **208**. While depicted as its own line **208** in the example of FIG. **2** for ease of explanation, in some examples the line **208** may be part the welding cable **126** shown in FIG. **1**. In the example of FIGS. **1** and **2**, the output power may be provided to the clamp **117** (and/or workpiece(s) **110**) via clamp cable **115**.
(45) In the example of FIGS. **1** and **2**, the welding power supply **108** includes power conversion circuitry **132** configured to convert the input power to output power (e.g., welding output power and/or other power). In some examples, the power conversion circuitry **132** may include circuit elements (e.g., transformers, rectifiers, capacitors, inductors, diodes, transistors, switches, and so forth) capable of converting the input power to output power. In the example of FIG. **2**, the power conversion circuitry **132** includes one or more controllable circuit elements **204**. In some examples, the controllable circuit elements **204** may comprise circuitry configured to change states (e.g., fire, turn on/off, close/open, etc.) based on one or more control signals. In some examples, the state(s) of the controllable circuit elements **204** may impact the operation of the power conversion circuitry **132**, and/or impact characteristics (e.g., current/voltage magnitude, frequency, waveform, etc.) of the output power provided by the power conversion circuitry **132**. In some examples, the controllable circuit elements **204** may comprise, for example, switches, relays, transistors, etc. In examples where the controllable circuit elements **204** comprise transistors, the transistors may comprise any suitable transistors, such as, for example MOSFETs, JFETs, IGBTs, BJTs, etc.
(46) In some examples, the controllable circuit elements **204** of the power conversion circuitry **132** may be controlled by (and/or receive control signals from) control circuitry **134** of the welding power supply **108**. In the examples of FIG. **2**, the welding power supply **108** includes control circuitry **134** electrically coupled to the power conversion circuitry **132**. In some examples, the control circuitry **134** operates to control the power conversion circuitry **132**, so as to ensure the power conversion circuitry **132** generates the appropriate welding power for carrying out the desired welding operation.
(47) In the example of FIG. **2**, the control circuitry **134** includes a weld controller **220** and a converter controller **222**. As shown the weld controller **220** and converter controller **222** are electrically connected. In some examples, the converter controller **222** controls the power conversion circuitry **132** (e.g., via the controllable circuit elements **204**), while the weld controller **220** controls the converter controller **222** (e.g., via one or more control signals). In some examples, the weld controller **220** may control the converter controller **222** based on weld parameters and/or weld operations input by the operator (e.g., via the operator interface **144**) and/or input programmatically. For example, an operator may input one or more target weld operations and/or weld parameters through the operator interface **144**, and the weld controller **220** may control the converter controller **222** based on the target weld operations and/or weld parameters. The converter controller **222** may in turn control the power conversion circuitry **132** (e.g., via the controllable circuit elements **204**) to produce output power in line with the weld operations and/or weld parameters. In some examples, the converter controller **222** may only send control signals to the power conversion circuitry **132** if an enable signal is provided by the weld controller **220** (and/or if the enable signal is set to true, on, high, 1, etc.).
(48) In the example of FIG. **2**, the weld controller **220** includes memory **224** and one or more processors **226**. In some examples, the one or more processors **226** may use data stored in the memory **224** to execute certain control algorithms. The data stored in the memory **224** may be received via the operator interface **144**, one or more input/output ports, a network connection, and/or be preloaded prior to assembly of the control circuitry **134**. In the example of FIG. **2**, the

memory **224** further comprises a weld program **300**, further discussed below. In some examples, the weld program **300** may make use of the processors **226** and/or memory **224**. Though not depicted, in some examples the converter controller **222** may also include memory and/or one or more processors.

(49) In the example of FIG. **2**, the control circuitry **134** is in electrical communication with one or more sensors **236** via line **210**. While shown as a separate line for ease of explanation in the example of FIG. **2**, in some examples, line **210** may be integrated into the weld cable **126** of FIG. **1**. In some examples, the control circuitry **134** may use the one or more sensors **236** to monitor the current and/or voltage of the output power and/or welding arc **150**. In some examples the one or more sensors **236** may be positioned on, within, along, and/or proximate to the wire feeder **140**, weld cable **126**, power supply **108**, and/or torch **118**. In some examples, the one or more sensors **236** may comprise, for example, current sensors, voltage sensors, impedance sensors, temperature sensors, acoustic sensors, trigger sensors, position sensors, angle sensors, and/or other appropriate sensors. In some examples, the control circuitry **134** may determine and/or control the power conversion circuitry **132** to produce an appropriate output power, arc length, and/or extension of wire electrode **250** based at least in part on feedback from the sensors **236**.

(50) In the example of FIG. **2**, the control circuitry **134** is also in electrical communication with the wire feeder **140** and gas supply **142**. In some examples, the control circuitry **134** may control the wire feeder **140** to output wire electrode **250** at a target speed and/or direction. For example, the control circuitry **134** may control the motor **219** of the wire feeder **140** to feed the wire electrode **250** to (and/or retract the wire electrode **250** from) the torch **118** at a target speed. In some examples, the control circuitry **134** may also control one or more motors and/or rollers of the wire feeder **120** within the welding torch **118** to feed and/or retract the wire electrode **250**. In some examples, the welding power supply **108** may control the gas supply **142** to output a target type and/or amount gas. For example, the control circuitry **134** may control a valve in communication with the gas supply **142** to regulate the gas delivered to the welding torch **118**.

(51) In some examples, a welding process may be initiated when the operator **116** activates the trigger **119** of the welding torch **118** (and/or otherwise activates the welding torch **118**). During the welding process, the welding power provided by the welding power supply **108** may be applied to the wire electrode **250** fed through the welding torch **118** in order to produce a welding arc **150** between the wire electrode **250** and the one or more workpieces **110**. The arc **150** may complete a circuit formed through electrical coupling of both the welding torch **118** and workpiece **110** to the welding power supply **108**. The heat of the arc **150** may melt portions of the wire electrode **250** and/or workpiece **110**, thereby creating a molten weld pool. Movement of the welding torch **118** (e.g., by the operator) may move the weld pool, creating one or more welds **111**.

(52) In some examples, the welding process may be initiated automatically and executed via control circuitry **134** in accordance with instructions stored in memory **224**, such as program **300**.

(53) When the welding process is finished, the operator **116** may release the trigger **119** (and/or otherwise deactivate the welding torch **118**). In some examples, the control circuitry **134** (e.g., the weld controller **220**) may detect that the welding process has finished. For example, the control circuitry **134** may detect a trigger release signal via sensor **236**. As another example, the control circuitry **134** may receive a torch deactivation command via the operator interface **144** (e.g., where the torch **118** is maneuvered by a robot and/or automated welding machine). In some examples, the current being applied to the welding torch **118** is monitored, as a change in the amount of current may indicate the end of the weld.

(54) In some examples, a weld may come to an end, such as a weld which is one or a plurality of welds being performed as part of a welding schedule. FIG. **4***a* shows an example depiction of the welding torch **118** and workpiece **110** at an end of the weld **111** as the welding process finishes. In the example of FIG. **4***a*, the weld **111** has been formed by the welding process, but the final portion of the weld **111** has yet to cool and is still a molten weld pool **404**. Because the welding process has

just finished, the welding torch **118** remains aimed at the weld pool **404**.

(55) In conventional welding systems, the control circuitry **134** might command the wire feeder **140** to stop feeding the wire electrode **250** after detecting that the welding process has finished. However, in the welding system **100** of the present disclosure, the control circuitry **134** activates the method or program **300** to control the wire electrode **250** to remain in or initiate motion at the end of a weld in response to detecting the welding process has finished, the weld has ended, and/or the end of the weld is imminent. In some examples, some or all of the program **300** may be implemented in machine readable instructions stored in memory **224** and/or executed by the one or more processors **226**. In some examples, some or all of the program **300** may be implemented in analog and/or discrete circuitry. In some examples, the program **300** may be configured to retract the wire electrode **250** away from the molten weld pool **404** created by the welding process in order to mitigate the possibility of the wire electrode **250** fusing to a contact tip.

(56) FIG. **3** is a flowchart representative of the program **300**. At block **302**, the program **300** performs a welding operation in accordance with a stored welding program, user input, etc. At block **304**, the program **300** monitors one or more welding parameters (e.g., of the power supply and/or welding program, etc.) and/or characteristics of the wire electrode, the workpiece, and/or the welding system. At block **306**, the program **300** determines that the weld has ended (e.g., the welding process has finished), and/or that the end of the weld is imminent (based on the monitored parameters and/or characteristics).

(57) In some examples, the program **300** may determine that the welding process has finished via detection by the control circuitry **134** (e.g., the weld controller **220**). In some examples, the control circuitry **134** may detect that the welding process has finished by way of a trigger release signal from sensor **236**. In some examples, the control circuitry **134** may detect that the welding process has finished via a signal sent through the connection (e.g., via weld cable **126**) between the welding torch **118** and the welding power supply **108**. For example, a signal (and/or change in voltage and/or current) may be detected by the control circuitry **134**, such as when the trigger **119** is activated and/or deactivated. In some examples, activating the trigger **119** may open or close a trigger circuit (not shown) in the welding torch **118**, while deactivating the trigger **119** may do the opposite. In some examples, the control circuitry **134** may detect that the welding process has finished via a signal detected from the operator interface **144**. For example, in examples where the torch **118** is maneuvered by a robot and/or automated welding machine, a human may terminate a welding process via the operator interface **144**, and the operator interface **144** may send a corresponding signal to the control circuitry **134**. In some examples, the welding process may be programmatically controlled (e.g., via instructions stored in memory **224** and/or executed by processor(s) **226**), and the termination of the welding process may be indicated to the control circuitry **134** (e.g., via an appropriate signal) by the program. In some examples, the control circuitry **134** may detect that the end of the weld via monitoring one or more welding parameters and/or outputs. For example, a change in the current provided to the welding torch **118** may indicate the end of the weld. While block **302** is shown as part of the program **300** in FIG. **3** for the sake of completeness, in some examples block **302** may be the trigger for executing program **300**, rather than being part of program **300**.

(58) At block **308**, the program **300** controls (e.g., via one or more signals) the wire feeder **140** (and/or torch **118**) to continue movement of the wire electrode **250** by retracting the wire electrode **250** in direction **113** for a time T.sub.x and/or a distance D.sub.x, as shown at block **310**. In some examples, this retraction of the wire electrode **250** ensures that any hot spot on the wire electrode **250** is moved relative to the contact tip **115** to prevent or mitigate the opportunity for fusion. In some examples, the time T.sub.x and/or distance D.sub.x may be stored in memory **224** (e.g., as a welding process) and/or set by an operator (e.g., via the operator interface **144**). In some examples, the program **300** may use the same wire feed speed employed in performing the weld, or a different wire feed speed may be used.

(59) In the example of FIG. **3**, after the expiration of time T.sub.x and/or retraction of the wire by distance D.sub.x, the program **300** proceeds to block **312** to command (e.g., via one or more signals) the wire feeder(s) **120**, **140** (and/or welding torch **118**) to advance the wire electrode **250** forward for a time T.sub.y and/or a distance D.sub.y, as shown at block **314**. In some examples, the time T.sub.y and/or distance D.sub.y may be stored in memory **224** (e.g., as a welding process) and/or set by an operator (e.g., via the operator interface **144**). In some examples, the time T.sub.y and/or distance D.sub.y may be the same as, greater than, or less than the time T.sub.x and/or distance D.sub.x. In some examples, the program **300** may use the same wire feed speed employed at block **302**, the wire feed speed set at block **308**, and/or a different wire feed speed. In some examples, the wire feeder unit **120** may be employed to retract (and/or subsequently advance) the wire electrode **250** without the use of the wire feeder **140**. The buffer **121** allows for a length of wire to push into a conduit or wire guide without damaging the wire electrode and/or the delivery mechanisms.

(60) At block **316**, the program **300** may optionally determine whether the wire electrode **250** has made contact with the contact tip or if contact has been avoided/removed. In some examples, the program **300** may determine there is contact if a short circuit is detected (e.g., if sensor **236** detects a current outside a predetermined range of current values and a voltage outside a predetermined range of voltage values). In some examples, the program **300** may determine that there is no contact if an open circuit is detected (e.g., if sensor **236** detects no or negligible current and a substantial voltage). In some examples, the program may determine whether there is contact through some other means (e.g., via a camera, thermal imaging device, spectrometer, spectrophotometer, etc.). As shown, if contact is still detected at block **316**, the program **300** returns to block **308** to address the fusion by moving the electrode wire **250** (e.g., retract or advance the wire). In some examples, the program **300** may additionally or alternatively increase current to reduce the opportunity for fusion. If no contact is detected at block **316**, the program **300** concludes that fusion has been successfully mitigated, and proceeds to block **318** in preparation for the next weld.

(61) FIG. **4***b* shows an example depiction of the welding torch **118** and workpiece **110** after the wire electrode **250** has been fed forward toward the workpiece **110** in direction **123**. As shown, the wire electrode **250** has advanced to a forward position in preparation for another weld. In the example of FIG. **4***b*, the wire electrode **250** has been fed forward to a position proximate the workpiece(s) **110**, and, as a result, initiation of the next weld is implemented without the need to wait for the wire electrode **250** to advance (e.g., from a retracted position). In the example of multiple welds being performed in succession, the advancement of the wire electrode **250** prior to initiation of the next weld may save a significant amount of time and resources in the aggregate. Each weld may have similar characteristics (e.g., length, penetration, workpiece material, power characteristics, etc.) or may have varying characteristics. Regardless, presentment of the wire electrode in advance of initiating the weld provides clear advantages for a variety of welding programs.

(62) The present method and/or system may be realized in hardware, software, or a combination of hardware and software. The present methods and/or systems may be realized in a centralized fashion in at least one computing system, or in a distributed fashion where different elements are spread across several interconnected computing or cloud systems. Any kind of computing system or other apparatus adapted for carrying out the methods described herein is suited. A typical combination of hardware and software may be a general-purpose computing system with a program or other code that, when being loaded and executed, controls the computing system such that it carries out the methods described herein. Another typical implementation may comprise an application specific integrated circuit or chip. Some implementations may comprise a non-transitory machine-readable (e.g., computer readable) medium (e.g., FLASH drive, optical disk, magnetic storage disk, or the like) having stored thereon one or more lines of code executable by a

machine, thereby causing the machine to perform processes as described herein.
(63) While the present method and/or system has been described with reference to certain implementations, 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 present method and/or system. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from its scope. Therefore, it is intended that the present method and/or system not be limited to the particular implementations disclosed, but that the present method and/or system will include all implementations falling within the scope of the appended claims.
(64) As used herein, "and/or" means any one or more of the items in the list joined by "and/or". As an example, "x and/or y" means any element of the three-element set {(x), (y), (x, y)}. In other words, "x and/or y" means "one or both of x and y". As another example, "x, y, and/or z" means any element of the seven-element set {(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)}. In other words, "x, y and/or z" means "one or more of x, y and z".
(65) As utilized herein, the terms "e.g.," and "for example" set off lists of one or more non-limiting examples, instances, or illustrations.
(66) Disabling of circuitry, actuators, and/or other hardware may be done via hardware, software (including firmware), or a combination of hardware and software, and may include physical disconnection, de-energization, and/or a software control that restricts commands from being implemented to activate the circuitry, actuators, and/or other hardware. Similarly, enabling of circuitry, actuators, and/or other hardware may be done via hardware, software (including firmware), or a combination of hardware and software, using the same mechanisms used for disabling.

Claims

1. A welding system, comprising: a wire feeder to advance and retract a welding wire; a welding power supply to provide power to a welding torch for establishing an electrical arc between the welding wire and a workpiece to perform a weld; and control circuitry configured to: determine an end of the weld and prior to initiation of another weld, wherein the determination of the end of the weld is based at least in part on data from a predetermined welding program; control the wire feeder to retract the welding wire for a first time or for a first distance in response to a determination the weld has ended; and control the wire feeder to advance the welding wire for a second time or for a second distance before initiation of another weld.
2. The system of claim 1, wherein the end of the weld corresponds to one of completion of the weld or a determination that the end of the weld is imminent.
3. The system of claim 1, wherein the welding program is defined by a welding process to perform a plurality of welds in succession.
4. The system of claim 1, wherein one or more of a length or a duration of the weld is predetermined in accordance with the predetermined welding program, the control circuitry further configured to determine the end of a weld based on the predetermined length or the predetermined duration.
5. The system of claim 1, wherein the predetermined welding program comprises a cyclic pattern of a plurality of similar or different welds.
6. The system of claim 1, wherein the input from a sensor corresponds to a current or a voltage of the power to the welding torch falling within a threshold range of values, or a change in the current or voltage falling within a threshold range of values.
7. The wire feeder of claim 1, wherein the control circuitry is further configured to control the welding power supply to provide power to the welding torch to initiate another weld after the second time or the second distance has been achieved.

8. The wire feeder of claim 1, wherein, upon determining that the end of the weld is imminent, the control circuitry is further configured to control the power supply to provide current to the welding torch as the welding wire retracts.
9. The wire feeder of claim 1, wherein, upon determining that the end of the weld is imminent, the control circuitry is further configured to control the power supply to end provision of power to the welding torch.
10. A wire feed system comprising: a drive mechanism configured to advance and retract a welding wire for establishing an electrical arc between the welding wire and a workpiece to perform a weld; and control circuitry configured to: receive a signal corresponding to a determination of an end of the weld, wherein a determination of the end of the weld is based at least in part on data from a predetermined welding program, and wherein the predetermined welding program is defined by a welding process to perform a plurality of welds in succession; control the drive mechanism to retract the welding wire for a first time or for a first distance; and control the drive mechanism to advance the welding wire for a second time or for a second distance prior to initiation of another weld.
11. The wire feed system of claim 10, wherein the first time is equivalent to the second time or the first distance is equivalent to the second distance.
12. The wire feed system of claim 10, wherein the first time is greater than the second time or the first distance is greater than the second distance.
13. The wire feed system of claim 10, wherein the welding wire is a cored wire.
14. The wire feed system of claim 13, wherein the cored wire comprises a metallic sheath enclosing a powdered metal.
15. The wire feed system of claim 10, wherein the welding wire is a solid wire.
16. The wire feed system of claim 10, wherein the control circuitry is further configured to initiate another weld after the second time.
17. The wire feed system of claim 10, wherein the wire feed system comprises a wire feeder configured to feed a welding wire to a welding torch.
18. The wire feed system of claim 10, wherein the wire feed system comprises a motorized torch with the drive mechanism incorporated within the torch.