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(54) LOAD SENSING FOR FRICTION WELDING

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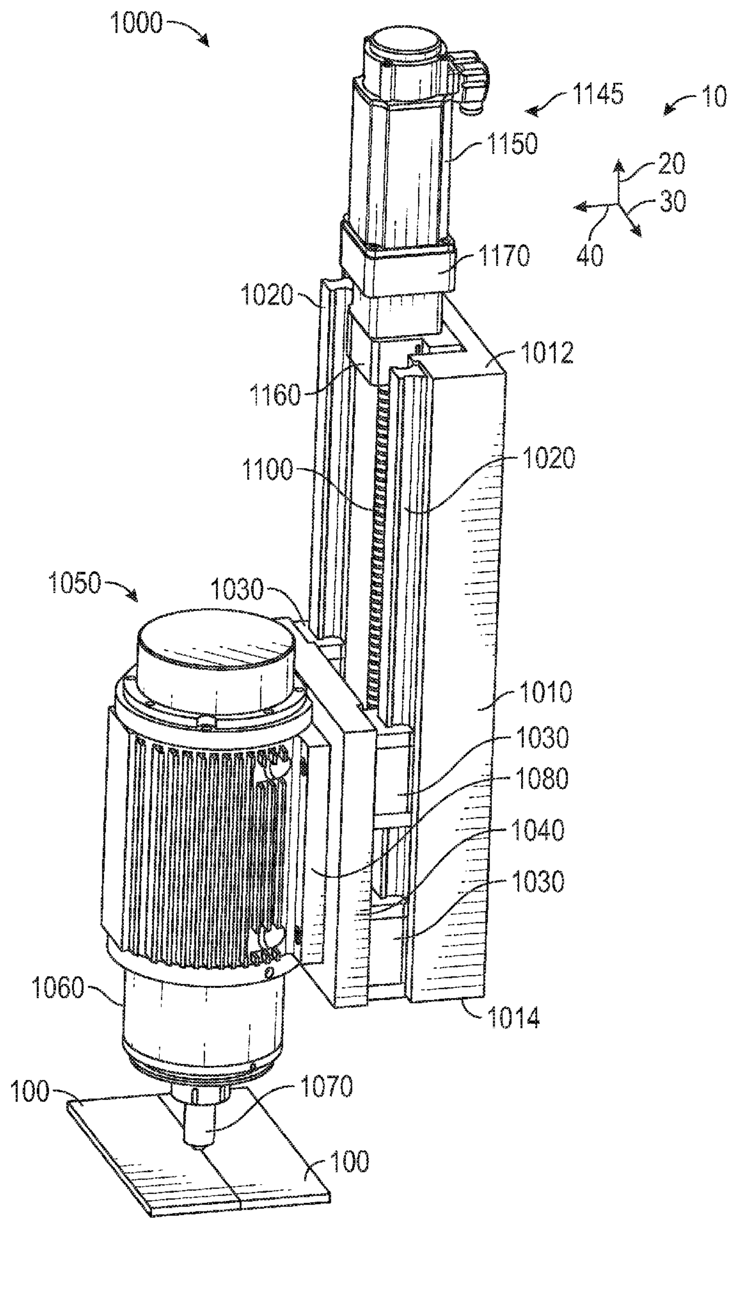
(57) **ABSTRACT**

A welder assembly includes a welding mechanism; a carriage plate, the welding mechanism fixedly coupled to the carriage plate; a translation assembly, the carriage plate fixedly coupled to the translation assembly, the translation assembly comprising a force sensor; a ball screw, the translation assembly moveably coupled to the ball screw; and, an axial drive motor coupled to the ball screw, wherein the ball screw is movably coupled to the translation assembly such that rotation of the axial drive motor forces linear translation of the translation assembly.



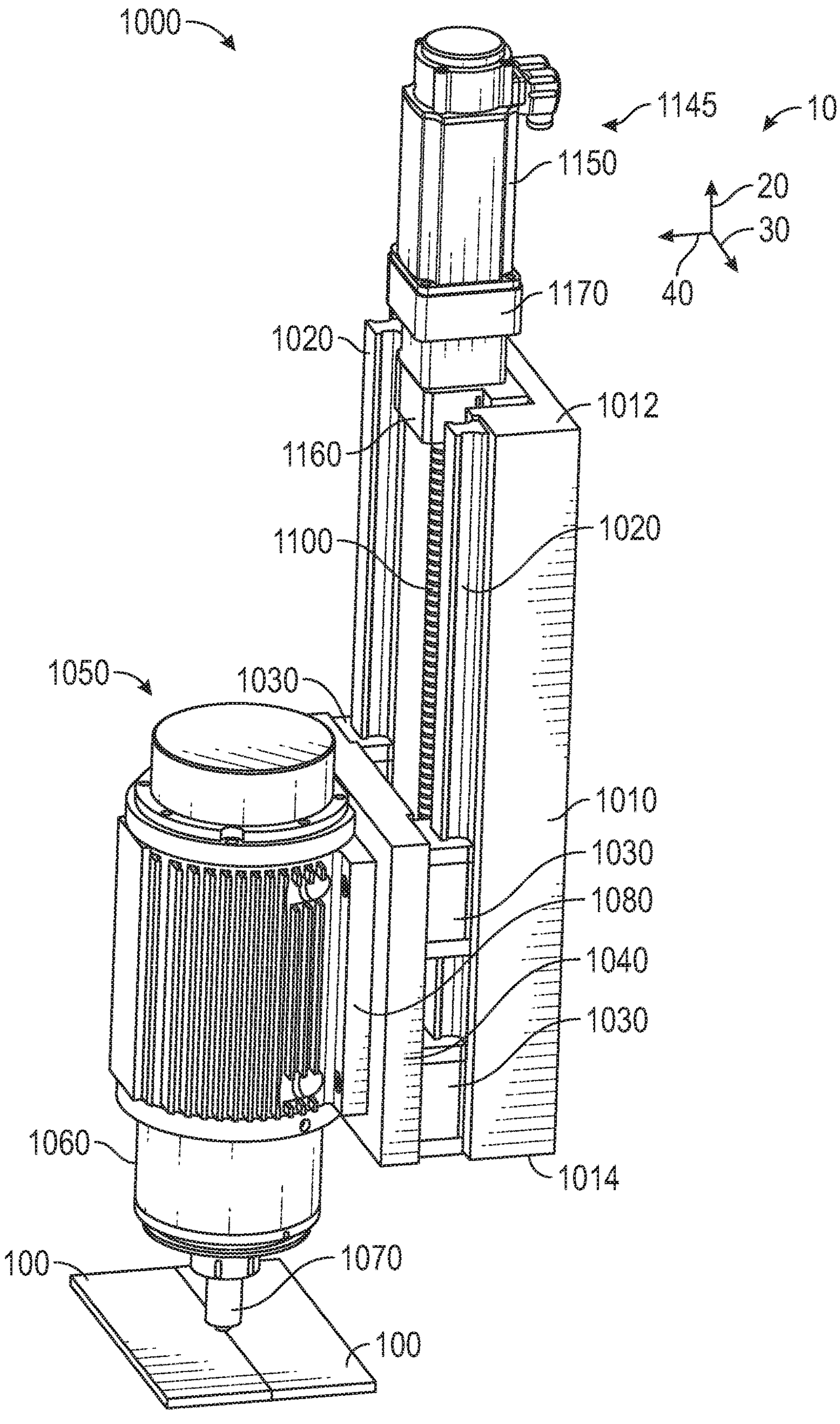

1000
1145
10
1150
20
30
40
1170
1020
1012
1160
1100
1020
1050
1030
1010
1030
1080
1040
1030
1060
1014
100
1070
100

FIG. 1

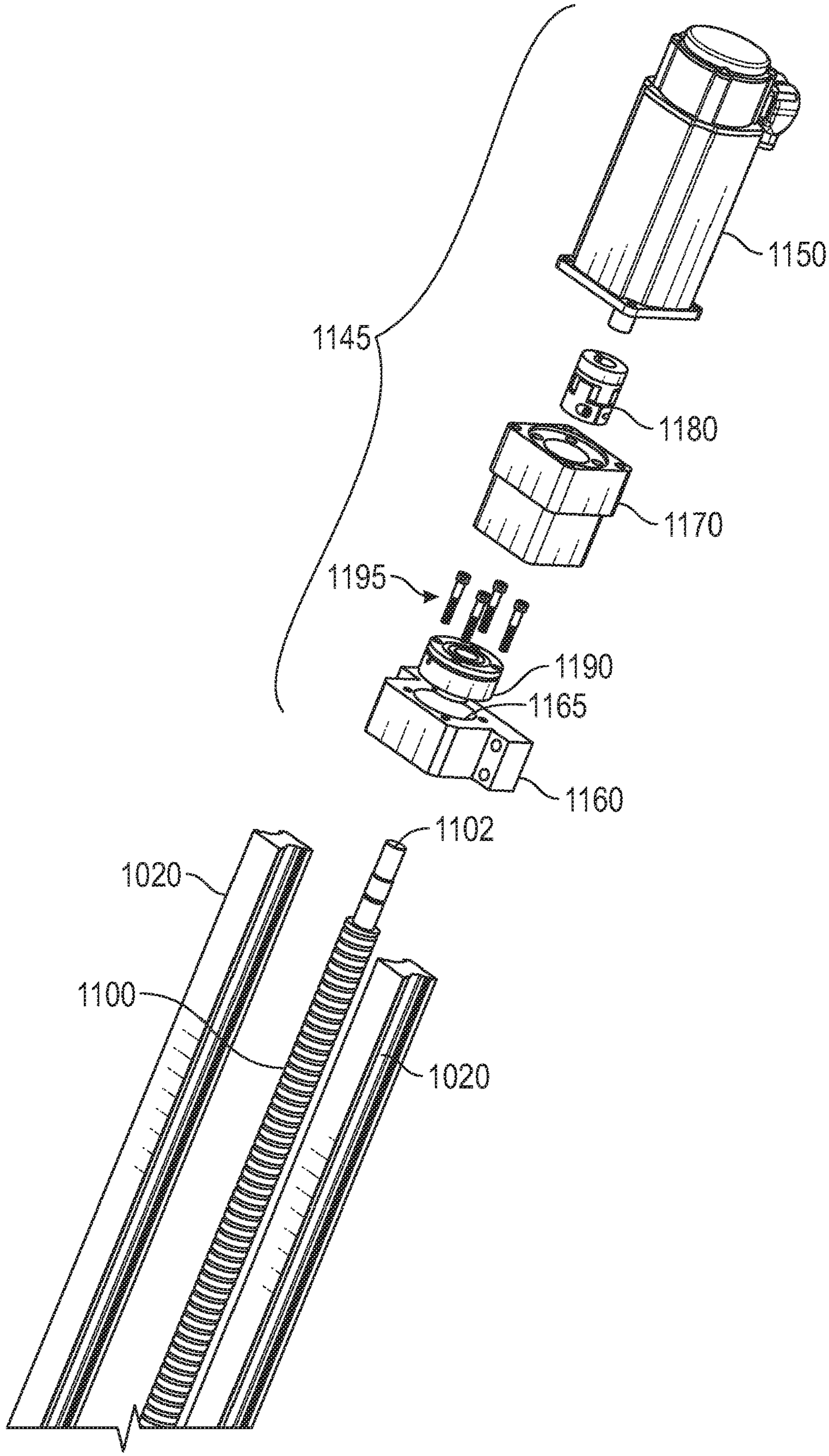


FIG. 2

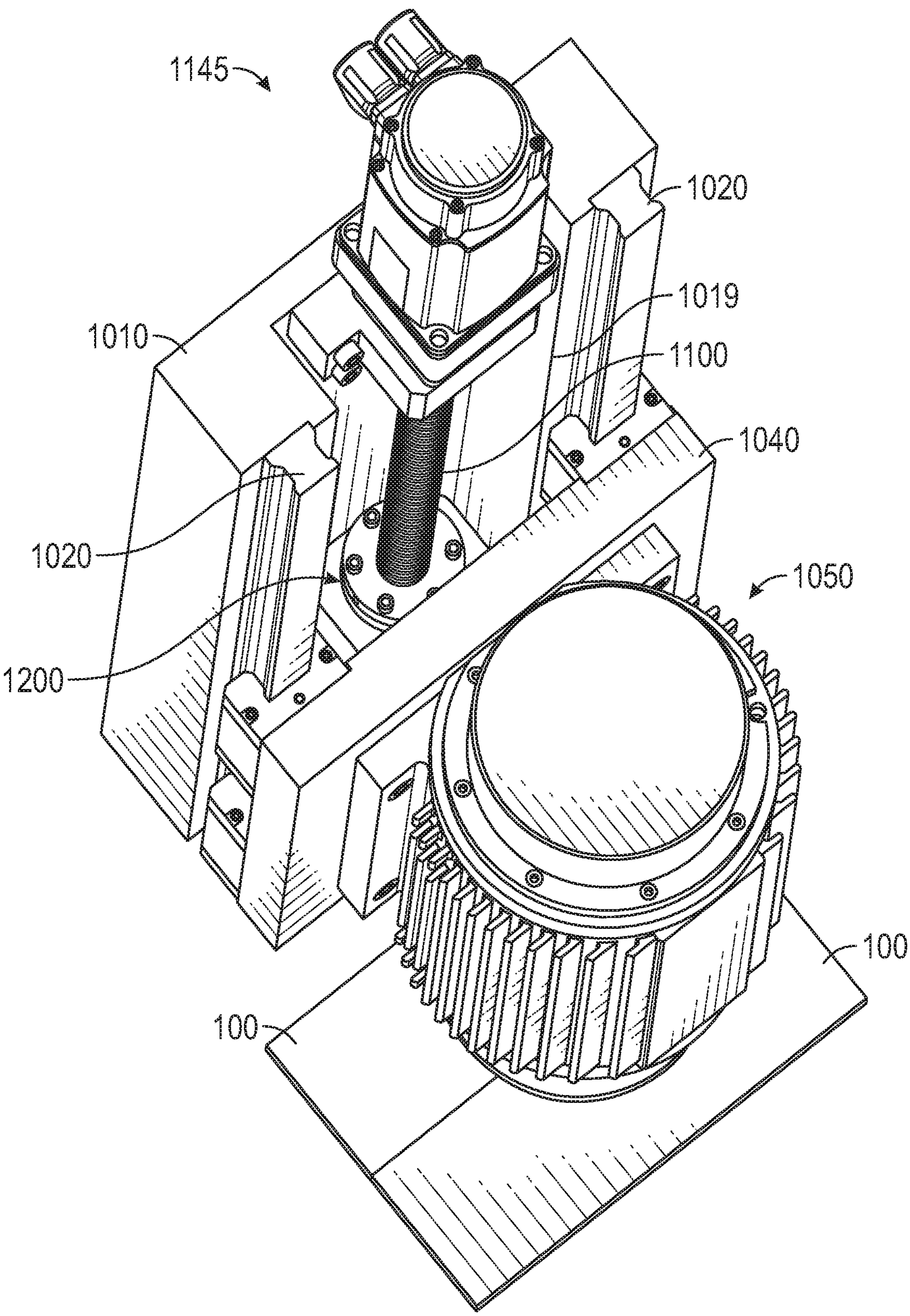


FIG. 3

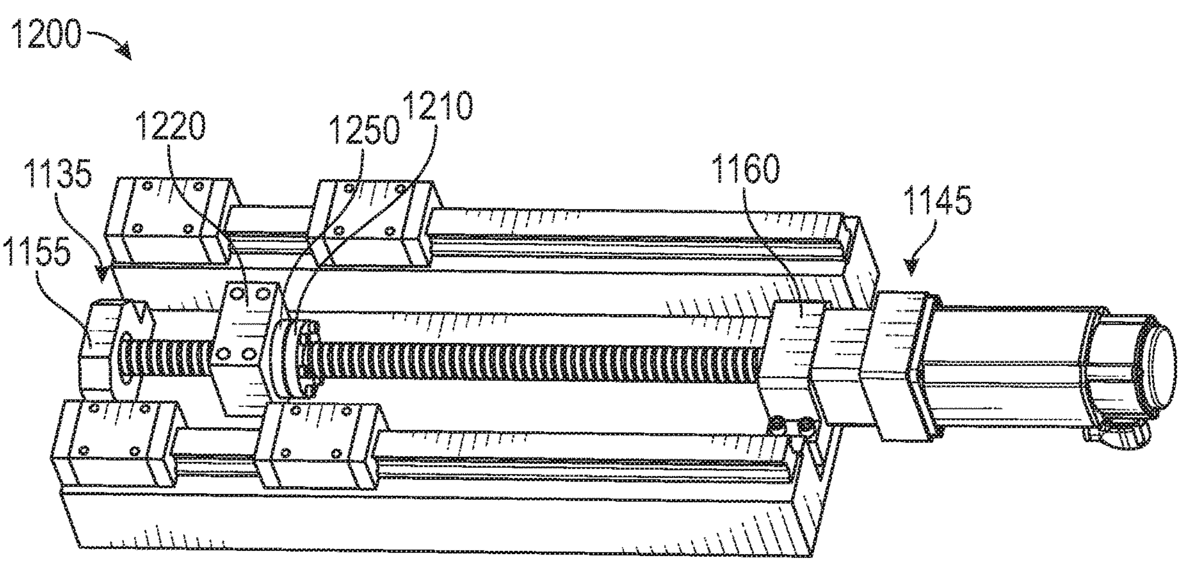

1200
1220
1250
1210
1135
1155
1160
1145

FIG. 4

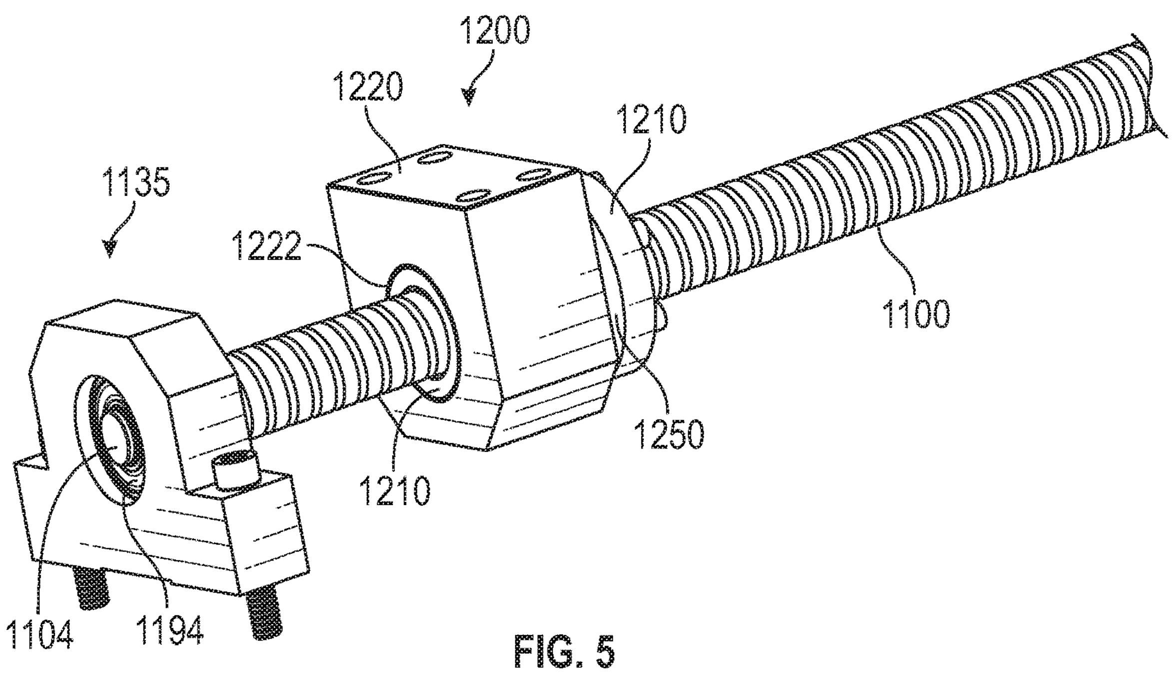

1200
1220
1210
1135
1222
1100
1250
1210
1104
1194

FIG. 5

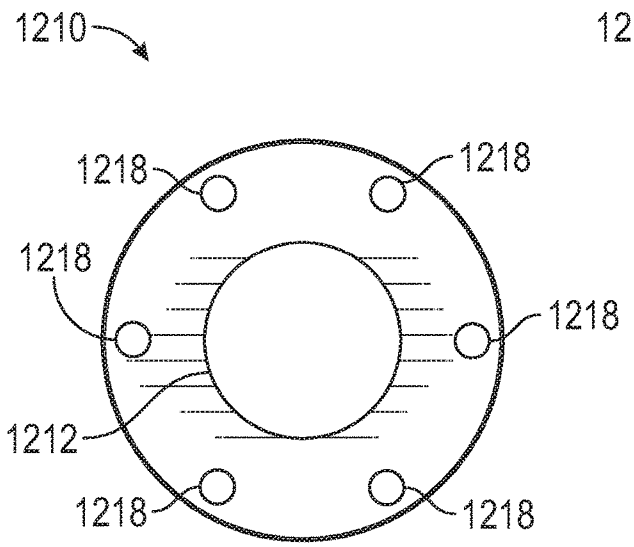


FIG. 6A

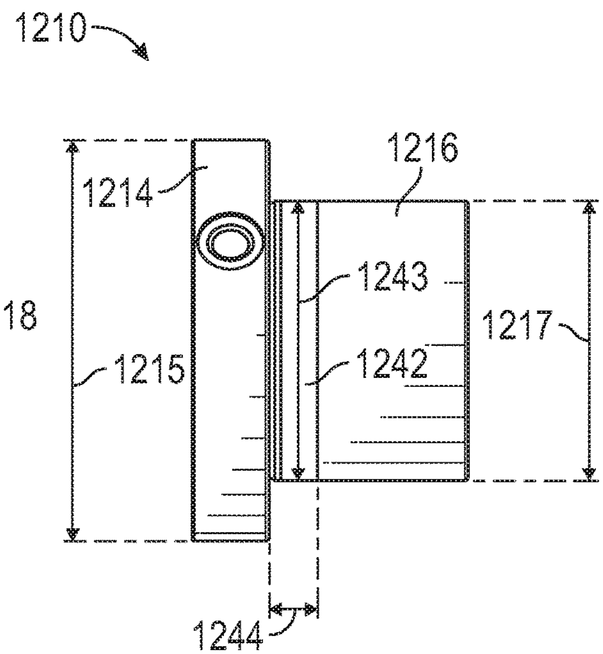


FIG. 6B

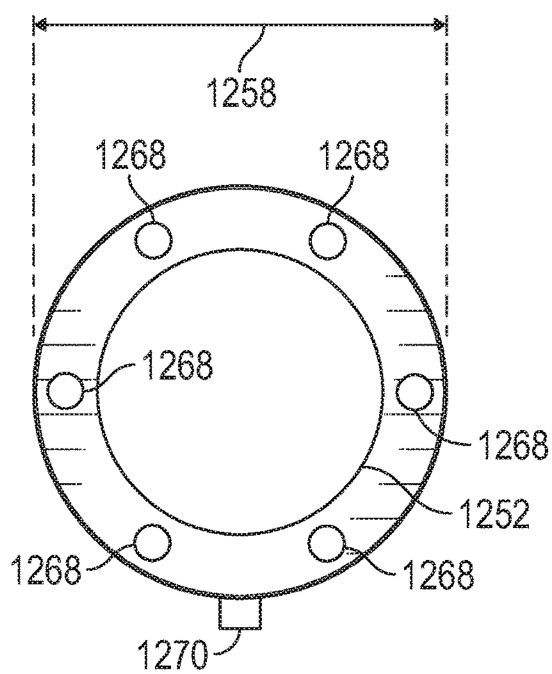


FIG. 6C

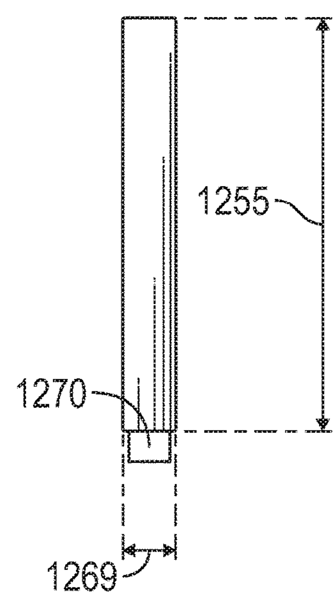


FIG. 6D

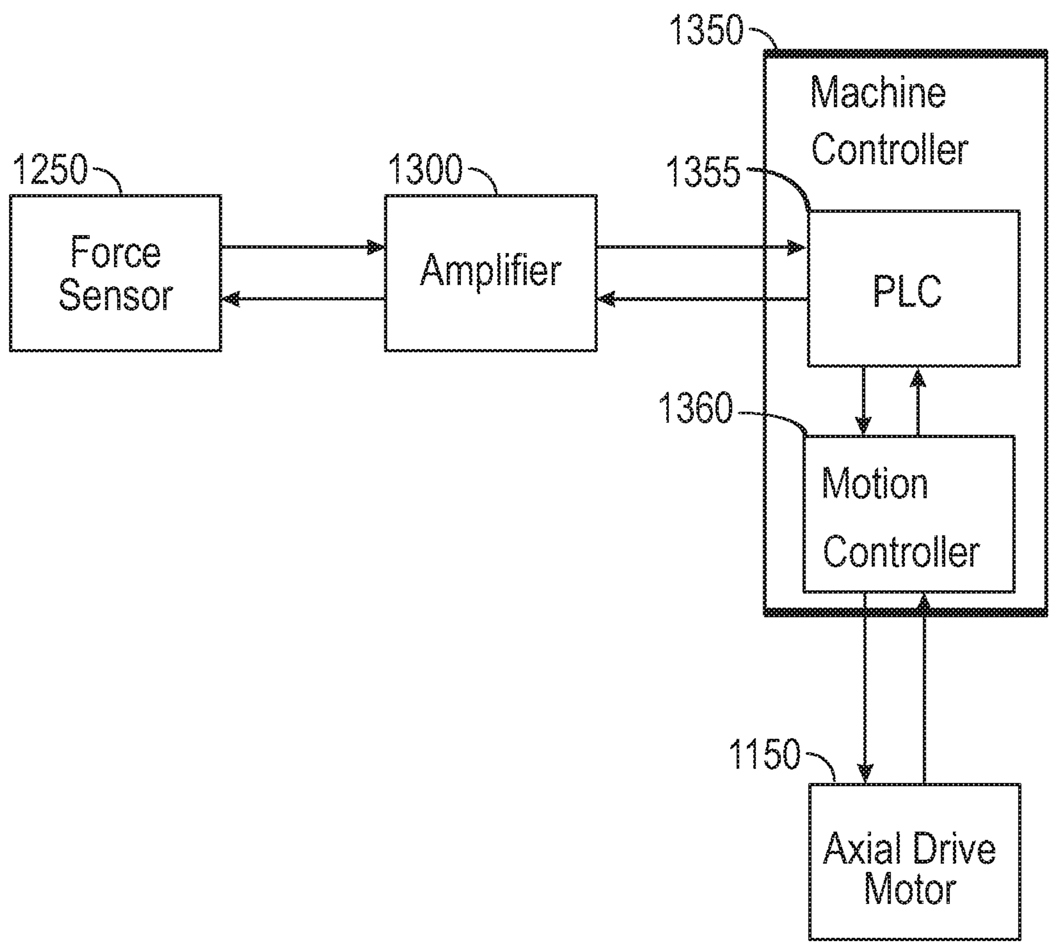

1350
Machine Controller
1250
Force Sensor
1300
Amplifier
1355
PLC
1360
Motion Controller
1150
Axial Drive Motor

FIG. 7

LOAD SENSING FOR FRICTION WELDING

TECHNICAL FIELD

[0001] This disclosure relates to friction welding. More specifically, this disclosure relates to load sensing in friction welding.

BACKGROUND

[0002] Welding can allow for the simple joining of at least two material workpieces. In friction welding, energy can be generated through friction by sliding workpieces with respect to one another or by use of a tool to generate energy of friction. At high enough energy, materials of the two material workpieces can be plasticized without melting and joined.

SUMMARY

[0003] It is to be understood that this summary is not an extensive overview of the disclosure. This summary is exemplary and not restrictive, and it is intended to neither identify key or critical elements of the disclosure nor delineate the scope thereof. The sole purpose of this summary is to explain and exemplify certain concepts of the disclosure as an introduction to the following complete and extensive detailed description.

[0004] A welder assembly includes a welding mechanism; a carriage plate, the welding mechanism fixedly coupled to the carriage plate; a translation assembly, the carriage plate fixedly coupled to the translation assembly, the translation assembly comprising a force sensor; a ball screw, the translation assembly moveably coupled to the ball screw; and, an axial drive motor coupled to the ball screw, wherein the ball screw is movably coupled to the translation assembly such that rotation of the axial drive motor forces linear translation of the translation assembly.

[0005] A force-sensing attachment for a welder assembly includes a carriage plate; a translation assembly, the carriage plate fixedly coupled to the translation assembly, the translation assembly comprising a force sensor; and a linear actuator, the translation assembly moveably coupled to the linear actuator.

[0006] A method of controlling a welding apparatus includes obtaining force sensor data from a force sensor located within a translation assembly, the translation assembly being fixedly coupled to a carriage plate and being movably coupled to a ball screw, wherein the translation assembly comprises a ball screw nut coupled to the ball screw and a nut housing coupled to the carriage plate, wherein the force sensor is arranged between the ball screw nut and the nut housing; and rotating the ball screw to modify the amount of force sensed by the force sensor.

[0007] Various implementations described in the present disclosure may include additional systems, methods, features, and advantages, which may not necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The features and components of the following figures are illustrated to emphasize the general principles of the present disclosure. Corresponding features and components throughout the figures may be designated by matching reference characters for the sake of consistency and clarity.

[0009] FIG. **1** is a perspective view of a welder assembly in accordance with one aspect of the current disclosure.

[0010] FIG. **2** is an exploded close-up view of the welder assembly of FIG. **1**.

[0011] FIG. **3** is a top perspective view of the welder assembly of FIG. **1**.

[0012] FIG. **4** is a side perspective view of the welder assembly of FIG. **1** with various parts hidden from view.

[0013] FIG. **5** is a close-up side perspective view of a ball screw and translation assembly of the welder assembly of FIG. **1**.

[0014] FIG. **6**A is a front view of a ball screw nut of the translation assembly of the welder assembly of FIG. **1**.

[0015] FIG. **6**B is a side view of the ball screw nut of FIG. **6**A.

[0016] FIG. **6**C is a front view of a force sensor of the translation assembly of the welder assembly of FIG. **1**.

[0017] FIG. **6**D is a side view of the force sensor of FIG. **6**C.

[0018] FIG. **7** is a block diagram of a feedback control system of the welder assembly of FIG. **1**.

DETAILED DESCRIPTION

[0019] The present disclosure can be understood more readily by reference to the following detailed description, examples, drawings, and claims, and the previous and following description. However, before the present devices, systems, and/or methods are disclosed and described, it is to be understood that this disclosure is not limited to the specific devices, systems, and/or methods disclosed unless otherwise specified, and, as such, can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting.

[0020] The following description is provided as an enabling teaching of the present devices, systems, and/or methods in its best, currently known aspect. To this end, those skilled in the relevant art will recognize and appreciate that many changes can be made to the various aspects of the present devices, systems, and/or methods described herein, while still obtaining the beneficial results of the present disclosure. It will also be apparent that some of the desired benefits of the present disclosure can be obtained by selecting some of the features of the present disclosure without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations to the present disclosure are possible and can even be desirable in certain circumstances and are a part of the present disclosure. Thus, the following description is provided as illustrative of the principles of the present disclosure and not in limitation thereof.

[0021] As used throughout, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “an element” can include two or more such elements unless the context indicates otherwise.

[0022] Ranges can be expressed herein as from "about" one particular value, and/or to "about" another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0023] For purposes of the current disclosure, a material property or dimension measuring about X or substantially X on a particular measurement scale measures within a range between X plus an industry-standard upper tolerance for the specified measurement and X minus an industry-standard lower tolerance for the specified measurement. Because tolerances can vary between different materials, processes and between different models, the tolerance for a particular measurement of a particular component can fall within a range of tolerances.

[0024] As used herein, the terms "optional" or "optionally" mean that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where said event or circumstance occurs and instances where it does not.

[0025] The word "or" as used herein means any one member of a particular list and also includes any combination of members of that list. Further, one should note that conditional language, such as, among others, "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain aspects include, while other aspects do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more particular aspects or that one or more particular aspects necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular aspect.

[0026] Disclosed are components that can be used to perform the disclosed methods and systems. These and other components are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these components are disclosed that while specific reference of each various individual and collective combinations and permutation of these may not be explicitly disclosed, each is specifically contemplated and described herein, for all methods and systems. This applies to all aspects of this application including, but not limited to, steps in disclosed methods. Thus, if there are a variety of additional steps that can be performed it is understood that each of these additional steps can be performed with any specific aspect or combination of aspects of the disclosed methods.

[0027] Disclosed is a load sensor for use in a machine and associated methods, systems, devices, and various apparatus. The load sensor can be utilized in friction welding. It would be understood by one of skill in the art that the disclosed load sensor is described in but a few exemplary embodiments among many. No particular terminology or description should be considered limiting on the disclosure or the scope of any claims issuing therefrom.

[0028] Friction welding processes encompass many different variants, including rotary friction welding, linear friction welding, and friction stir welding (FSW). In each case, friction can heat the material to a plastic state in conjunction with an applied force to create a weld. In some situations, no melting occurs, and, in such applications the processes are classified as solid-state welding

[0029] One embodiment of a friction welder assembly **1000** is disclosed and described with reference to FIG. **1**. The friction welder assembly **1000** of the current aspect can be a friction stir welding assembly. In various aspects, features of the friction welder assembly **1000** can be utilized in applications not related to friction stir welding, such as CNC milling, sensing milling cutting forces, sonic welding, or various other force-sensing applications. A reference coordinate system **10** can be defined with a z-direction **20** being up and down, an x-direction **30** being orthogonal to the z-direction **20** and defined as "left and right," and a y-direction **40** being orthogonal to both the x-direction **30** and the z-direction **20** and defined as "front and back." The friction welder assembly **1000** can be configured to be attached or connected to a milling machine or other similar manufacturing apparatus. The friction welder assembly **1000** can be utilized to accomplished friction stir welding processes in various aspects. For the sake of the current disclosure, friction stir welding can comprise the process of plunging a tool into a plurality of workpieces to be joined along a joint between the workpieces and rotating the tool to generate frictional welding of the workpieces. For the sake of the current disclosure, plunging can occur in the z-direction **20**. The rotating tool can then be translated linearly to accomplish welding along an entirety of the joint. For the sake of the current disclosure, the linear translation for joining can occur in the x-direction **30** or the y-direction **40**, or both. In various aspects, joining can occur along radii or curvature.

[0030] The friction welder assembly **1000** can comprise a support **1010**. In various aspects, the support **1010** can be attached, connected, or otherwise mounted to a milling machine or other similar manufacturing machine. As such, the friction welder assembly **1000** in various aspects can represent the "z-axis drive" of such a machine. Linear rails **1020** can be attached or connected to the support **1010**. The linear rails **1020** can serve as guides and/or load bearing elements for rail runners **1030** to travel along. In various aspects, the linear rails **1020** and the rail runners **1030** can be connected with respect to one another in various relationships, such as ball bearings, lubricated sliders, or various other low-friction relationships. In various aspects, the rail runners **1030** can be decoupled from the linear rails **1020**. In various aspects, the rail runners **1030** can be independently movable in at least one direction with respect to the linear rails **1020**. In various aspects, the rail runners **1030** can be arranged and placed in relationship to the linear rails **1020** such that the rail runners **1030** are movable in only one direction with respect to the linear rails **1020**. In various aspects, the arrangement of the linear rails **1020** and rail runners **1030** can be reversed. In various aspects, frictional force exhibited by the connection between the linear rails **1020** and the rail runners **1030** can be de minimis with respect to the amount of force loads exhibited within the friction welder assembly **1000** and, thus, can be ignored. Rail runners **1030** can be attached or connected to a carriage plate **1040** in various aspects. In various aspects, the welding assembly **1000** can be utilized in box guide way construction or linear guide construction as would be understood by one of skill in the art.

[0031] A welding mechanism **1050** can comprise a spindle motor **1060** and a tool **1070**. The tool **1070** can be attached to the spindle motor **1060** and can be configured to engage a plurality of workpieces **100** for welding. The welding mechanism **1050** can be connected or attached to the carriage plate **1040** by a mount **1080** that can connect or attach to the spindle motor **1060**.

[0032] Various attachment, connection, or mount apparatus can be used within the scope of the current disclosure. Attachments or connections can be achieved by mechanical coupling, such as by screws, fasteners, rivets, or the like; by joining, such as by welding, co-molding, forging, or various other joints; or by adhesion, such as with glues or other adhesives, among others. One of skill in the art would understand that the various connections or attachments could be utilized within the scope of the current disclosure.

[0033] Translational motion of the welding mechanism **1050** into the workpieces **100** can be achieved by coupling of a ball screw **1100** to the carriage plate **1040** in arrangement to translate rotation of the ball screw **1100** into linear motion. The ball screw **1100** can be coupled along one end to an axial drive motor **1150**. The axial drive motor **1150** can generate rotational energy of the ball screw **1100**. In various aspects, the ball screw **1100** can be replaced with various linear actuators, including but limited to machine screws, solenoids, gear arrangements, hydraulics, and piston assemblies, among other types of linear actuators.

[0034] Various elements cited in this paragraph can comprise an upper end assembly **1145**. A thrust coupling **1160** can be attached or connected to the support **1010** proximate an upper end **1012** of the support **1010**. The support can also define a lower end **1014**. The thrust coupling **1160** can serve as a connection point of a motor mount **1170**, which can be attached or connected to the thrust coupling **1160**. The axial drive motor **1150** can be attached or connected to the motor mount **1170**.

[0035] As seen with reference to FIG. **2**, the axial drive motor **1150** can be coupled to an upper end **1102** of the ball screw **1100** using a coupling **1180**. A thrust bearing **1190** can be utilized to distribute force loads within the upper end assembly **1145**. In the current aspect, the thrust coupling **1160** can define a bearing recess **1165** sized to accept the thrust bearing **1190**. Fasteners **1195** are shown and can be utilized to attach the motor mount **1170** to the thrust coupling **1160**.

[0036] As seen with reference to FIG. **3**, a translation assembly **1200** can be seen located within a channel **1019** of the support **1010**. The channel **1019** can provide a location between the linear rails **1020** for location of various elements to drive the welding mechanism **1050** into engagement with the workpieces **100**. The translation assembly **1200** can be driven by the ball screw **1100** and coupled to the carriage plate **1040** to translate the rotational motion of the ball screw **1100** into linear motion of the welding mechanism **1050**.

[0037] With reference to FIG. **4**, the translation assembly **1200** can be seen when the carriage plate **1040** and the remaining elements of the welding mechanism **1050** are removed from view. A lower end assembly **1135** can also be seen at a lower end **1104** (seen with reference to FIG. **5**) of the ball screw **1100** and can comprise a thrust bearing **1194** (seen with reference to FIG. **5**) located within a thrust coupling **1155** in similar relationship as the thrust bearing **1190** and the thrust coupling **1160**. The translation assembly **1200** can comprise a ball screw nut **1210** that can be connected or attached to a nut housing **1220**. The nut housing **1220** can further be attached or connected to the carriage plate **1040**, and, when done, translational motion of the translation assembly **1200** can cause motion of the carriage plate **1040** and thereby the welding mechanism **1050**.

[0038] Downward forces of welding can be in excess of 100 kN (100,000 Newtons) when friction welding aluminum depending on thickness and application. As such, the elements of the various assemblies can experience extreme forces and, in some cases, large variations in force. Because of the large variations in force, it is possible that the tool **1070** can be in varying engagement with the workpieces **100**. If the tool **1070** is not in constant engagement with the workpieces **100**, the weld can be compromised, and the welding mechanism **1050** can be unreliable for performing desired friction welding. As such, the inclusion of a force sensing capability can allow the operator of the welder assembly **1000** some feedback as to how the tool **1070** is engaging with the workpieces **100**.

[0039] A force sensor **1250** can be arranged between the ball screw nut **1210** and the nut housing **1220** to sense the amount of force being applied to the workpieces **100**. Maintenance of constant welding force can be critical to the success of a weld. In various aspects, welding loads can spike above 2.5× the expected load for rating purposes. As a result, constant downforce on the workpieces **100** can be supplied by engagement of the axial drive motor **1150** turning the ball screw **1100**, which therein causes the ball screw nut **1210** to translate linearly in the direction of the ball screw **1100** which is substantially in the z-direction **20**. As such, the downward force supplied can bear on the ball screw nut **1210**, through the force sensor **1250** to the nut housing **1220**, thereby allowing the force sensor **1250** to supply reliable reading of the force supplied to the tool **1070** and, thereby, into the workpieces **100**.

[0040] Various types of force sensor mechanisms can be utilized within the scope of the disclosure. One suitable force sensor mechanism can be a strain gauge load cell. In various aspects, a piezoelectric load sensor can be utilized. In various aspects, multiple force sensor mechanisms can be utilized in series or in parallel. In various aspects, the multiple force sensor mechanisms can be of the same type of load sensing arrangement, and in various aspects multiple different force sensor mechanisms can be utilized.

[0041] As seen with reference to FIG. **5**, the nut housing **1220** can define a nut recess **1222** that can be sized to accept a portion of the ball screw nut **1210**. The force sensor **1250** can be sized to accept a portion of the ball screw nut **1210** and can be arranged between the nut housing **1220** and another portion of the ball screw nut **1210**.

[0042] The arrangements of the ball screw nut **1210** and the force sensor **1250** can be seen in greater detail with reference to FIGS. **6A-6D**. The ball screw nut **1210** and the force sensor **1250** of the current aspect can be about annular, and, in various aspects, can be symmetrical about a center axis. As can be seen, the ball screw nut **1210** defines a ball screw recess **1212** arranged centrally to the ball screw nut **1210** along an entire length of the ball screw nut **1210**. The ball screw recess **1212** accepts the ball screw **1100** and includes corresponding features to allow the ball screw nut **1210** to translate along the ball screw **1100** in response to turning of the ball screw **1100**. The ball screw nut **1210** can comprise a shoulder portion **1214** and a collar portion **1216**. The shoulder portion **1214** can be of a greater diameter **1215** than a diameter **1217** of the collar portion **1216**. In various aspects, the diameters **1215**, **1217** can be of various measurements. In the current aspect, the diameter **1215** can be about 80.00 mm and the diameter **1217** can be about 55.95 mm. The ball screw nut **1210** can define a plurality of fastener apertures **1218** spaced about equally about the circumference of the ball screw nut **1210** and adapted for attachment of the ball screw nut **1210** to the nut housing **1220**. The collar portion **1216** can be defined adjacent to a sensor location portion **1242**. The sensor location portion **1242** can be said to be a part of the collar portion **1216** in various aspects. The sensor location portion **1242** can be of a length **1244** of about 10 mm and of a diameter **1243** of about 56.00 mm, or about 0.05 mm greater than the diameter **1217** of the collar portion **1216** generally. In various aspects, the dimensions of the various parts can be of various shapes and sizes.

[0043] Similarly, the force sensor **1250** can be ring-shaped in various aspects. In various aspects, the force sensor **1250** can be an assembly of parts, wherein a portion of the force sensor **1250** can be comprised of assembly parts and a portion of the force sensor **1250** can be comprised of sensing parts such as piezo electrics. In various aspects, the force sensor **1250** can comprise multiple sensing elements arranged about the force sensor **1250**. The force sensor **1250** can be about ring shaped and have a diameter **1255** of about 80.00 mm, or as close to the diameter **1215** as possible. In various aspects, the diameter **1255** can be different from the diameter **1215**. In the current aspect, the force sensor **1250** can define a collar recess **1252** sized to accept the collar portion **1216** of the ball screw nut **1210**. In the current aspect, a diameter **1258** of the collar recess **1252** can be about 56.00 mm, or 0.05 mm larger than a diameter **1217** of the collar portion **1216** and about the same diameter as the diameter **1243** of the sensor location portion **1242**. As such, the force sensor **1250** can be located along the sensor location portion **1242** with a tight fit—and, in some cases, with an interference fit—to ensure a snug engagement with the ball screw nut **1210** and the nut housing **1220**. Similarly, the force sensor **1250** can define a plurality of fastener apertures **1268**. The fastener apertures **1268** can match the location, size, and number of fastener apertures **1218** located on the ball screw nut **1210**. The force sensor **1250** can be of a width **1269** of about 10 mm, or about the same as the length **1244** of the sensor location portion **1242**. The force sensor **1250** can also comprise an electrical connector **1270** for communication of data from the force sensor **1250**. The connector **1270** can be sized smaller than the width **1269** to avoid being damaged when the force sensor **1250** is arranged between the ball screw nut **1210** and the nut housing **1220**.

[0044] In various aspects, the force sensor **1250** can be connected to an amplifier **1300** as seen with reference to FIG. **7**. The amplifier **1300** can also be connected to a Machine Controller **1350**, which can be integrated with a machine that controls the friction welder assembly **1000**. In various aspects, the machine controller **1350** can comprise a programmable logic controller (PLC) **1355** and a motion controller **1360**. Sensed data of loads placed on the load cell of the force sensor **1250** can generate an electrical signal that can be communicated to the amplifier **1300**. The electrical signal can be amplified by the amplifier **1300**, and the amplified signal can then be communicated to the machine controller **1350**. Based on the sensed load, the machine controller **1350** can generate instructions to a central control system to regulate the welding process of the welder assembly **1000**. In particular, in response to the sensed load on the force sensor **1250**, the machine controller **1350** can decide that the load is too great or too little to achieve the desired constancy of welding forces. The machine controller **1350** can then communicate instructions to the machine—in various aspects, a CNC milling machine or similar apparatus—to actuate the axial drive motor **1150**. Actuation of the axial drive motor **1150** can cause the ball screw **1100** to turn, thereby actuating the translation assembly **1200** through the engagement of the ball screw nut **1210** with the ball screw **1100**. The ball screw nut **1210** can then actuate against the nut housing **1220**, with the force generated translating into the workpieces **100** through the welding mechanism **1050**. When the ball screw nut **1210** is forced against the nut housing **1220**, the force sensor **1250** can read the amount of force imparted between the two elements, thereby generating a new electrical signal in response to the sensed force, thereby renewing the cycle of control. In various aspects, control algorithms can be generated to ensure constant workpiece engagement by monitoring the load imparted on the workpieces **100**—and the rate of change thereof—through the feedback loop of the force sensor **1250** through the amplifier **1300** to the machine controller **1350**. In various aspects, the machine controller **1350** can in turn communicate back through the amplifier **1300** to the force sensor **1250**.

[0045] The arrangements of the machine controller **1350** and the various apparatus disclosed herein can allow the welder assembly **1000** to maintain constant engagement force at a preset force level. In various aspects, the welder assembly **1000** can maintain constant engagement force at maximum of 5% deviance from a spec force value. In various aspects, the welder assembly **1000** can maintain constant engagement force at maximum of 10% deviance from a spec force value. In various aspects, the welder assembly **1000** can maintain constant engagement force at maximum of 15% deviance from a spec force value. One should note that conditional language, such as, among others, "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more particular embodiments or that one or more particular embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment.

[0046] It should be emphasized that the above-described embodiments are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Any process descriptions or blocks in flow diagrams should be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included in which functions may not be included or executed at all, may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. Further, the scope of the present disclosure is intended to cover any and all combinations and sub-combinations of all elements, features, and aspects discussed above. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure.

That which is claimed is:

1. A welder assembly comprising:

a welding mechanism;

a carriage plate, the welding mechanism fixedly coupled to the carriage plate;

a translation assembly, the carriage plate fixedly coupled to the translation assembly, the translation assembly comprising a force sensor;

a ball screw, the translation assembly moveably coupled to the ball screw; and,

an axial drive motor coupled to the ball screw,

wherein the ball screw is movably coupled to the translation assembly such that rotation of the axial drive motor forces linear translation of the translation assembly.

2. The welder assembly of claim **1**, the translation assembly comprising a ball screw nut and a nut housing, wherein the force sensor is arranged between the ball screw nut and the nut housing such that linear force applied to the ball screw nut is applied to the force sensor and to the nut housing.

3. The welder assembly of claim **2**, wherein the ball screw nut defines a shoulder portion and a collar portion, wherein the force sensor defines a collar recess sized to accept the collar portion.

4. The welder assembly of claim **3**, wherein the collar portion further comprises a sensor location portion, the sensor location portion being of a diameter to engage the force sensor in interference fit.

5. The welder assembly of claim **2**, wherein the force sensor is electrically connected to a circuit, the circuit configured to read force sensor data to determine the force applied to the force sensor.

6. The welder assembly of claim **5**, wherein the circuit is electrically connected to the axial drive motor, and wherein the circuit includes control instructions to control the axial drive motor in response to force sensor data.

7. The welder assembly of claim **6**, wherein the control instructions are configured to maintain constant force.

8. The welder assembly of claim **6**, wherein the control instructions are configured to maintain within 5% deviance from constant force.

9. The welder assembly of claim **2**, wherein the welding mechanism comprises a spindle motor coupled to the carriage plate and a tool connected to the spindle motor.

10. The welder assembly of claim **2**, wherein the axial drive motor is coupled to a motor mount, wherein the motor mount is coupled to a support, wherein the ball screw is rotatably coupled to the support at an upper end of the ball screw and at a lower end of the ball screw, and wherein the support comprises a plurality of linear rails.

11. The welder assembly of claim **10**, wherein a plurality of rail runners are fixedly coupled to the carriage plate, the rail runners arranged to engage in linear actuation with the linear rails.

12. A force-sensing attachment for a welder assembly, the force-sensing attachment comprising:

a carriage plate;

a translation assembly, the carriage plate fixedly coupled to the translation assembly, the translation assembly comprising a force sensor; and

a linear actuator, the translation assembly moveably coupled to the linear actuator.

13. The force-sensing attachment of claim **12**, the translation assembly comprising an inner collar coupled to the linear actuator and a housing coupled to the carriage plate, wherein the force sensor is arranged between the inner collar and the housing such that linear force applied to the inner collar by the linear actuator is applied to the force sensor and to the housing.

14. The force-sensing attachment of claim **13**, wherein the inner collar defines a shoulder portion and a collar portion, wherein the force sensor defines a collar recess sized to accept the collar portion.

15. The force-sensing attachment of claim **14**, wherein the collar portion further comprises a sensor location portion, the sensor location portion being of a diameter to engage the force sensor in interference fit.

16. The force-sensing attachment of claim **13**, wherein the force sensor is electrically connected to a circuit, the circuit configured to read force sensor data to determine the force applied to the force sensor.

17. The force-sensing attachment of claim **16**, wherein the circuit is electrically connected to the linear actuator, and wherein the circuit includes control instructions to control the linear actuator in response to force sensor data.

18. The force-sensing attachment of claim **17**, wherein the control instructions are configured to maintain force within 10% of a spec force value

19. The force-sensing attachment of claim **17**, wherein the control instructions are configured to maintain force within 15% of a spec force value

20. A method of controlling a welding apparatus, the method comprising:

obtaining force sensor data from a force sensor located within a translation assembly, the translation assembly being fixedly coupled to a carriage plate and being movably coupled to a ball screw, wherein the translation assembly comprises a ball screw nut coupled to the ball screw and a nut housing coupled to the carriage plate, wherein the force sensor is arranged between the ball screw nut and the nut housing; and

rotating the ball screw to modify the amount of force sensed by the force sensor.

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