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Robotic gripper apparatus

Abstract

A robotic gripper apparatus for an automated additive manufacturing production system (AAMPS) includes a pair of gripping assemblies. Each gripping assembly is moveable in a transverse direction between a first position in which the gripping assembly engages an AAMPS workpiece and a second position in which the gripping assembly is disengaged from the AAMPS workpiece. Each gripping assembly includes a gripping element that defines an interface slot configured to receive the AAMPS workpiece. The interface slot is defined by a pair of transversely extending edges of the gripping element and a longitudinal edge of the gripping element disposed between the pair of transversely extending edges.

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Background/Summary

FIELD

(1) The present disclosure relates to a robotic gripper apparatus and a robot including the robotic gripper apparatus.

BACKGROUND

(2) The statements in this section merely provide background information related to the present disclosure and may not constitute prior art.

(3) Industrial robots have been used for a variety of manufacturing operations, including by way of example, welding, placement of parts for subsequent fabrication or assembly operations, and moving parts from one location to another such as retrieving parts from a storage location and moving them to an assembly station. These industrial robots include end effectors, which are essentially the hands of the robot. In many applications, the end effectors are configured as

grippers, which grasp a part and move the part to a different location or manipulate the position of the part for manufacturing operations.

(4) Recently, additive manufacturing machines (i.e., 3-D printers) have been developed to manufacture parts out of metals, plastics, and other materials. Industrial robots including end effectors are used to move an automated additive manufacturing production system (AAMPS) workpiece from a storage location to the additive manufacturing machine. These end effectors come in a variety of configurations depending on the particular manufacturing operation. However, end effectors often lack proper handling of the workpiece and mechanical repeatability.

(5) These issues related to robotic end effectors, among other issues related to robotic end effectors, are addressed by the present disclosure.

SUMMARY

(6) This section provides a general summary of the disclosure and is not a comprehensive disclosure of its full scope or all of its features.

(7) In one form, the present disclosure provides a robotic gripper apparatus for an automated additive manufacturing production system (AAMPS). The robotic gripper apparatus includes a pair of gripping assemblies. Each gripping assembly is moveable in a transverse direction between a first position in which the gripping assembly engages an AAMPS workpiece and a second position in which the gripping assembly is disengaged from the AAMPS workpiece. Each gripping assembly includes a gripping element defining an interface slot configured to receive the AAMPS workpiece. The interface slot is defined by a pair of transversely extending edges of the gripping element and a longitudinal edge of the gripping element disposed between the pair of transversely extending edges.

(8) In variations of the robotic gripper apparatus of the above paragraph, which may be implemented individually or in any combination: the interface slot is elongated; the interface slots define an arcuate surface; the interface slot is open at one of the pair of transversely extending edges; the interface slot is sloped; when each gripping assembly is in the first position, the interface slots are configured to have an interference fit with the AAMPS workpiece; each gripping assembly includes a connecting member secured to a respective gripping element at a first end and to an actuator at an opposing second end; the gripping elements are disposed between the connecting members; the connecting member is secured to the respective gripping element via mechanical fasteners; an actuator is operable to move the pair of gripping assemblies between the first and second positions; and a positioning probe coupled to one of the pair of gripping assemblies.

(9) In another form, the present disclosure provides a robotic gripper apparatus for an automated additive manufacturing production system (AAMPS). The robotic gripper apparatus includes an actuator assembly and a pair of gripping assemblies. The actuator assembly includes a pair of movable members. Each gripping assembly is secured to a respective movable member and is movable in a transverse direction between a first position in which the gripping assembly engages an AAMPS workpiece and a second position in which the gripping assembly is disengaged from the AAMPS workpiece. Each gripping assembly includes a gripping element defining an interface slot configured to receive the AAMPS workpiece. The interface slot is defined by a pair of transversely extending edges of the gripping element and a longitudinal edge of the gripping element disposed between the pair of transversely extending edges.

(10) In variations of the robotic gripper apparatus of the above paragraph, which may be implemented individually or in any combination: the interface slot is elongated; the interface slot is open at one of the pair of transversely extending edges; the interface slot is sloped; each gripping element includes an attachment portion and an engaging portion, the attachment portion is secured to a respective movable member and the engaging portion defines the interface slot; the attachment portion includes a plurality of openings, and a slope of the interface slot is adjustable based on which one of the plurality of openings the respectable movable member is secured to; each gripping assembly includes a connecting member secured to a respective gripping element at a first

end and to a respective movable member at an opposing second end; and the gripping elements are disposed between the connecting members.
(11) In yet another form, the present disclosure provides a robotic gripper apparatus for an automated additive manufacturing production system (AAMPS). The robotic gripper apparatus includes an actuator assembly and a pair of gripping assemblies. The actuator assembly includes a pair of movable members. Each gripping assembly is secured to a respective movable member and movable in a transverse direction between a first position in which the gripping assembly engages an AAMPS workpiece and a second position in which the gripping assembly is disengaged from the AAMPS workpiece. Each gripping assembly includes a gripping element and a connecting member. The gripping element includes an attachment portion and an engaging portion. The attachment portion is secured to a respective movable member and the engaging portion defines an interface slot configured to receive the AAMPS workpiece. The connecting member is secured to a respective gripping element at a first end and a respective movable member at an opposing second end. The interface slot is defined by a pair of transversely extending edges of the gripping element and a longitudinal edge of the gripping element is disposed between the pair of transversely extending edges.
(12) Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

Description

DRAWINGS
(1) In order that the disclosure may be well understood, there will now be described various forms thereof, given by way of example, reference being made to the accompanying drawings, in which:
(2) FIG. **1** is a perspective view of a robot including a gripper apparatus in an open position according to the principles of the present disclosure;
(3) FIG. **2** is a perspective view of the gripper apparatus of FIG. **1** in a closed position;
(4) FIG. **3** is an exploded view of the gripper apparatus of FIG. **1**;
(5) FIG. **4** is a top view of the gripper apparatus of FIG. **1** in the closed position;
(6) FIG. **5** is a top view of the gripper apparatus of FIG. **1** in the open position;
(7) FIG. **6** is a front view of the gripper apparatus of FIG. **1** in the closed position;
(8) FIG. **7** is a perspective view of the gripper apparatus of FIG. **1** in the closed position grasping the AAMPS workpiece;
(9) FIG. **8** is a perspective view of the gripper apparatus of FIG. **1** moving the AAMPS workpiece from a workstation to an automated additive manufacturing machine (3-D printer); and
(10) FIG. **9** is a schematic block diagram showing components of the gripper apparatus of FIG. **1**.
(11) The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.
DETAILED DESCRIPTION
(12) The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.
(13) As shown in FIG. **1**, a robot **10** for grasping and moving an automated additive manufacturing production system (AAMPS) workpiece **12** is provided. In the example illustrated, the AAMPS workpiece **12** is a carbon platform. However, the AAMPS workpiece **12** may be other suitable objects in which a component may be built using an automated additive manufacturing machine **13** (FIG. **8**; i.e., a 3-D printer). In the example illustrated, the robot **10** is positioned on and secured to a movable platform **14** (i.e., the platform **14** moves to a workstation where the robot **10** grasps and

moves the workpiece **12** from a supporting rack, for example, to the additive manufacturing machine **13**). The platform **14** may be moved automatically or manually. However, in some variations, the robot **10** may be positioned on a fixed platform located near or at the workstation.
(14) The robot **10** includes a robot arm **16** and a robotic gripper apparatus **18**. The robot arm **16** includes a plurality of segments **20** connected to each other at joints **22**, thereby allowing the robot **10** to have multiple degrees of freedom. The robot arm **16** is also secured to the movable platform **14** at a first end. In some variations, the robot arm **16** includes an optional adapter (not shown) that is adapted to be secured to the movable platform **14**.
(15) With reference to FIGS. **1**-**9**, the robotic gripper apparatus **18** includes an actuator assembly **24** and a pair of gripping assemblies **26**. The actuator assembly **24** is secured to an opposing second end of the robot arm **16** (FIGS. **1**, **7**, and **8**). The actuator assembly **24** includes a body **25**, a motor **28** (FIG. **9**), and a pair of movable members or arms **30** (FIGS. **2**-**5**, **7**, and **8**). The body **25** is secured to the opposing second end of the robot arm **16**. The motor **28** is associated with the body **25** (e.g., disposed within the body **25**) and is in electrical communication with a controller **32** (FIG. **1**) of the robot **10**. The controller **32** may be in communication with the motor **28** via, for example, an internet, Wi-Fi, Bluetooth®, Zigbee®, power-line carrier communication (PLCC), or cellular connection or any other wired or wireless communication protocol. The motor **28** is operable between an OFF mode and an ON mode. In one form, the motor **28** may be an electric motor such as a brushless drive motor. Each arm **30** is operatively connected to the motor **28** via a respective rail or connecting member **34** and is allowed to move in a transverse direction (i.e., transverse to a longitudinal direction of the body **25**). For example, when the motor **28** is in the OFF mode, the arms **30** are inhibited from moving in the transverse direction. When the motor **28** is in the ON mode, the arms **30** are allowed to move in the transverse direction between an open state and a closed state.
(16) Each gripping assembly **26** is secured to a respective arm **30** and is movable in the transverse direction between a first or closed position (FIGS. **2**, **4**, and **6**-**8**) and a second or open position (FIGS. **1** and **5**). Stated differently, each gripping assembly **26** is secured to the respective arm such that when the respective arm **30** is moved to the closed state, the gripping assembly **26** is moved the closed position (when the gripping assemblies **26** are in the closed position, the gripping assemblies **26** are spaced apart from each other), and when the respective arm **30** is in the open state, the gripping assembly **26** is in the open position.
(17) Each gripping assembly **26** includes a connecting member **36** and a gripping element **38**. The connecting members **36** may have a uniform thickness and are positioned outwardly relative to the arms **30** and gripping elements **38** (i.e., the arms **30** and the gripping elements **38** are positioned between the connecting members **36**). As shown in FIG. **3**, each connecting member **36** includes a plurality of first openings **40** located at or near a first end **44***a* thereof and a plurality of second openings **42** located at or near an opposing second end **44***b* thereof. In the example illustrated, the first end **44***a* may have a generally rectangular shape and the second end **44***b* may have a generally triangular shape such that the second end **44***b* includes a greater surface area than a surface area of the first end **44***a*. However, in some variations, the first end **44***a* and the second end **44***b* may be of other suitable shapes or may be of the same shape. The connecting member **36** may be mechanically fastened to a first side of a respective arm **30** at the first end **44***a* via fasteners **45***a* (e.g., rivets, bolts, screws, etc.) extending through the first openings **40**. Similarly, the connecting member **36** may be mechanically fastened to a respective gripping element **38** at the second end **44***b* via fasteners **45***b* (e.g., rivets, bolts, screws, etc.) extending through the second openings **42**. In some variations, the connecting member **36** may be attached to the respective arm **30** and the respective gripping element **38** via welding or any other suitable attachment means.
(18) Each gripping element **38** includes an attachment portion **46** configured to couple to the connecting member and an engaging portion **48** configured to interface with the AAMPS workpiece **12**. The attachment portion **46** extends from the engaging portion **48** and has a thickness

that is less than a thickness of the engaging portion **48**. The attachment portion **46** is also secured to an opposing second side of a respective arm **30** (FIGS. **4** and **5**; i.e., the respective arm **30** is positioned between the attachment portion **46** of the gripping element **38** and the first end **44***a* of the connecting member **36**). The attachment portion **46** includes a plurality of openings **50***a*, **50***b*, **50***c* extending therethrough. The openings **50***a*, **50***b*, **50***c* may be aligned with each other along an arc. A fastener **45***c* extends through an opening **53** of the respective arm **30** and through one of the openings **50***a*, **50***b*, **50***c* of the attachment portion **46**, thereby securing the gripping element **38** to the respective arm **30**. In this way, a slope of an elongated interface slot **52** of the engaging portion **48** is adjustable based on which one of the plurality of openings **50***a*, **50***b* **50***c* the fastener **45***c* extends through. For example, the slope of the interface slot **52** will be greater if the fastener **45***c* extends through opening **50***a* than if the fastener **45***c* extends through opening **50***b*. In another example, the slope of the interface slot **52** will be greater if the fastener **45***c* extends through opening **50***b* than if the fastener **45***c* extends through opening **50***c*.

(19) The engaging portion **48** includes a pair of transversely extending edges **54***a*, **54***b*, a pair of longitudinally extending edges **56***a*, **56***b*, and the interface slot **52**. The longitudinally extending edge **56***b* includes openings **57** that are aligned with the second openings **42** of the connecting member **36**. In this way, the fasteners **45***b* extend through the openings **42**, **57** to secure the connecting member **36** and the gripping element **38** to each other. The interface slot **52** is configured to receive the AAMPS workpiece **12**. In one form, the interface slot **52** is configured to have an interference fit with the handle **58** of the AAMPS workpiece **12** when the gripping assembly **26** interfaces with the AAMPS workpiece **12**.

(20) The interface slot **52** is defined by the pair of transversely extending edges **54***a*, **54***b* and the longitudinally extending edge **56***a*. The interface slot **52** is open at the transversely extending edge **54***a* and the longitudinally extending edge **56***a*. The interface slot **52** corresponds to the handle **58** of the AAMPS workpiece **12** (i.e., the shape of the interface slot **52** corresponds to the shape of the handle **58** of the AAMPS workpiece **12**). As shown in FIGS. **2** and **6**, the interface slot **52** includes an arcuate back surface **60***a* and opposing flat surfaces **60***b* that may contact the handle **58** of the AAMPS workpiece **12** when the gripping assemblies **26** are in the first position.

(21) In an example operation, with the robotic gripper apparatus **18** in the open position (i.e., the gripper assemblies **26** and arms **30** are in the open position), the gripper assemblies **26** re positioned such that the gripper elements **38** are provided on either side of the handle **58** of the AAMPS workpiece **12**. The robotic gripper apparatus **18** is positioned in the closed position (i.e., the gripper assemblies **26** and the arms **30** are in the closed position) to have the gripper elements **38** engage with and form an interference fit with the handle **58** of the AAMPS workpiece **12**. That is, the handle **58** of the AAMPS workpiece **12** is received in the interface slots **52** (FIGS. **7** and **8**), thereby securing the AAMPS workpiece **12** to the pair of gripping assemblies **26**. The robot **10** moves and positions the AMMPS workpiece **12** at a specific destination (e.g., AAM machine **13**, fixture at staging area, etc.) and once at the destination, the robotic gripper apparatus **18** is provided in the open position to release the AAMPS workpiece **12**. That is, the gripping assemblies **26** and arms **30** transversely move to the open position (FIGS. **1** and **5**) such that the interface slots **52** disengage from the AAMPS workpiece **12**.

(22) In one form, since the gripper assemblies **26** form an interference fit with the AAMPS workpiece **12**, the tolerance of the robotic gripper apparatus **18** with respect to the AAMS workpiece **12** can be tight (e.g., ±0.5 mm). Accordingly various techniques may be employed to accurately locate and engage with the AAMS workpiece **12**. For example, in one form, the robotic gripper apparatus **18** includes a positioning probe **62** coupled to one of the pair of gripping assemblies **26** and is employed by the controller **32** to perform a localization routine to determine a positional offset of the robot **10** with respect to a defined nominal position of the gripper robotic gripper apparatus **18**. Such a localization routine is disclosed in Applicant's co-pending application titled “METHOD AND SYSTEM FOR POSITIONING A ROBOTIC SYSTEM” which is

commonly owned with the present application and the contents of which are incorporated herein by reference in its entirety. In addition to or in lieu of the positioning probe, other locating and positioning techniques may be employed. For example, a vision system having one or more cameras distributed about the robot **10** may be used to control operation of the robotic gripper apparatus **18**.

(23) The robotic gripper apparatus **18** of the present disclosure provides the benefit of repeatability when moving AAMPS workpieces between the workstation and the automated additive manufacturing machine. The robotic gripper apparatus **18** of the present disclosure also provides the benefit of maintaining a working surface (i.e., a surface containing the additively manufactured component) of the AAMPS workpiece planar when moving the AAMPS workpiece from the automated additive manufacturing machine back to the workstation. While specific benefits are provided, it should be readily understood that other benefits may be realized with the robotic gripper apparatus **18** of the present disclosure.

(24) In this application, the term “controller” and/or “module” may refer to, be part of, or include: an Application Specific Integrated Circuit (ASIC); a digital, analog, or mixed analog/digital discrete circuit; a digital, analog, or mixed analog/digital integrated circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor circuit (shared, dedicated, or group) that executes code; a memory circuit (shared, dedicated, or group) that stores code executed by the processor circuit; other suitable hardware components (e.g., op amp circuit integrator as part of the heat flux data module) that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip.

(25) The term memory is a subset of the term computer-readable medium. The term computer-readable medium, as used herein, does not encompass transitory electrical or electromagnetic signals propagating through a medium (such as on a carrier wave); the term computer-readable medium may therefore be considered tangible and non-transitory. Non-limiting examples of a non-transitory, tangible computer-readable medium are nonvolatile memory circuits (such as a flash memory circuit, an erasable programmable read-only memory circuit, or a mask read-only circuit), volatile memory circuits (such as a static random access memory circuit or a dynamic random access memory circuit), magnetic storage media (such as an analog or digital magnetic tape or a hard disk drive), and optical storage media (such as a CD, a DVD, or a Blu-ray Disc).

(26) The apparatuses and methods described in this application may be partially or fully implemented by a special purpose computer created by configuring a general-purpose computer to execute one or more particular functions embodied in computer programs. The functional blocks, flowchart components, and other elements described above serve as software specifications, which can be translated into the computer programs by the routine work of a skilled technician or programmer.

(27) Unless otherwise expressly indicated herein, all numerical values indicating mechanical/thermal properties, compositional percentages, dimensions and/or tolerances, or other characteristics are to be understood as modified by the word “about” or “approximately” in describing the scope of the present disclosure. This modification is desired for various reasons including industrial practice, material, manufacturing, and assembly tolerances, and testing capability.

(28) As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean “at least one of A, at least one of B, and at least one of C.”

(29) The description of the disclosure is merely exemplary in nature and, thus, variations that do not depart from the substance of the disclosure are intended to be within the scope of the disclosure. Such variations are not to be regarded as a departure from the spirit and scope of the disclosure.

Claims

1. A robotic gripper apparatus for an automated additive manufacturing production system (AAMPS), the robotic gripper apparatus comprising: a pair of gripping assemblies movable relative to each other in a transverse direction between a first position in which the gripping assemblies engage an AAMPS workpiece and a second position in which the gripping assemblies are disengaged from the AAMPS workpiece, each gripping assembly including a gripping element defining an interface slot configured to receive the AAMPS workpiece, wherein the interface slot is defined by a pair of transversely extending edges of the gripping element and a longitudinal edge of the gripping element disposed between the pair of transversely extending edges.
2. The robotic gripper apparatus of claim 1, wherein the interface slot is elongated.
3. The robotic gripper apparatus of claim 1, wherein the interface slots define an arcuate surface.
4. The robotic gripper apparatus of claim 1, wherein the interface slot is open at one of the pair of transversely extending edges.
5. The robotic gripper apparatus of claim 1, wherein the interface slot is sloped.
6. The robotic gripper apparatus of claim 1, wherein when each gripping assembly is in the first position, the interface slots are configured to have an interference fit with the AAMPS workpiece.
7. The robotic gripper apparatus of claim 1, wherein each gripping assembly includes a connecting member, the connecting member is secured to a respective gripping element at a first end and to an actuator at an opposing second end.
8. The robotic gripper apparatus of claim 7, wherein the gripping elements are disposed between the connecting members.
9. The robotic gripper apparatus of claim 7, wherein the connecting member is secured to the respective gripping element via mechanical fasteners.
10. The robotic gripper apparatus of claim 1 further comprising an actuator operable to move the pair of gripping assemblies between the first and second positions.
11. The robotic gripper apparatus of claim 1 further comprising a positioning probe coupled to one of the pair of gripping assemblies.
12. A robotic gripper apparatus for an automated additive manufacturing production system (AAMPS), the robotic gripper apparatus comprising: an actuator assembly including a pair of movable members; and a pair of gripping assemblies, each gripping assembly secured to a respective movable member and movable in a transverse direction between a first position in which the gripping assembly engages an AAMPS workpiece and a second position in which the gripping assembly is disengaged from the AAMPS workpiece, each gripping assembly including a gripping element defining an interface slot configured to receive the AAMPS workpiece, wherein the interface slot is defined by a pair of transversely extending edges of the gripping element and a longitudinal edge of the gripping element disposed between the pair of transversely extending edges.
13. The robotic gripper apparatus of claim 12, wherein the interface slot is elongated.
14. The robotic gripper apparatus of claim 12, wherein the interface slot is open at one of the pair of transversely extending edges.
15. The robotic gripper apparatus of claim 12, wherein the interface slot is sloped.
16. The robotic gripper apparatus of claim 12, wherein each gripping element includes an attachment portion and an engaging portion, the attachment portion is secured to a respective movable member and the engaging portion defines the interface slot.
17. The robotic gripper apparatus of claim 16, wherein the attachment portion includes a plurality of openings, and wherein a slope of the interface slot is adjustable based on which one of the plurality of openings the respectable movable member is secured to.
18. The robotic gripper apparatus of claim 12, wherein each gripping assembly includes a

connecting member, the connecting member is secured to a respective gripping element at a first end and to a respective movable member at an opposing second end.

19. The robotic gripper apparatus of claim 18, wherein the gripping elements are disposed between the connecting members.

20. A robotic gripper apparatus for an automated additive manufacturing production system (AAMPS), the robotic gripper apparatus comprising: an actuator assembly including a pair of movable members; and a pair of gripping assemblies, each gripping assembly secured to a respective movable member and movable in a transverse direction between a first position in which the gripping assembly engages an AAMPS workpiece and a second position in which the gripping assembly is disengaged from the AAMPS workpiece, each gripping assembly including: a gripping element including an attachment portion and an engaging portion, the attachment portion secured to a respective movable member and the engaging portion defining an interface slot configured to receive the AAMPS workpiece; and a connecting member secured to a respective gripping element at a first end and a respective movable member at an opposing second end, wherein the interface slot is defined by a pair of transversely extending edges of the gripping element and a longitudinal edge of the gripping element disposed between the pair of transversely extending edges.