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(71) Applicant: **NIKON CORPORATION** [JP/JP]; Shinagawa Intercity Tower C, 2-15-3, Konan, Minato-ku, Tokyo 108-6290 (JP).

(72) Inventors: **MAI, Rocky**; 636 Birch Avenue, San Mateo, CA 94404 (US). **POON, Alex, Ka Tim**; 158 Elisha Lane, San Ramon, CA 94583 (US). **KESVVANI, Gaurav**; 1123 Foster City Blvd.,#3, Foster City, CA 94404 (US). **LEE, Sandy**; 3106 Colebrook Lane, Dublin, CA 94568 (US).

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(54) Title: GRIPPER ASSEMBLY USING ELASTIC MEMBERS DEFORMED WITH VISCOUS FLUID

(57) Abstract: A gripper assembly (16) for selectively gripping an object (12) includes a gripper subassembly (24) having an elastic member (24A), and a deformer assembly (24E) that urges a gripper fluid (24B) against the elastic member (24A) to deform the elastic member (24A) and form one or more protrusions (24C) that engage the object (12). The gripper subassembly (24) can include a gripper frame (24D) that engages the elastic member (24A). The gripper frame (24D) includes one or more frame apertures (24H), and each protrusion (24C) extends through the gripper frame (24D) and engages the object (12).

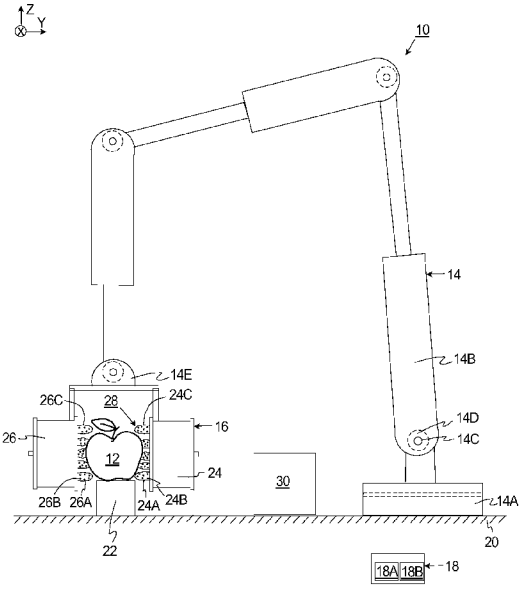


Fig. 1

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GRIPPER ASSEMBLY USING ELASTIC MEMBERS DEFORMED WITH VISCOUS FLUID

RELATED APPLICATION

[0001] This application claims priority on U.S. Provisional Application No: 62/806,529 filed on February 15, 2019, and entitled "GRIPPER ASSEMBLY USING ELASTIC MEMBERS DEFORMED WITH VISCOUS FLUID". As far as permitted, the contents of U.S. Provisional Application No: 62/806,529 is incorporated herein by reference.

BACKGROUND

[0002] Robotic arm assemblies are used to move and position one or more objects. A typical robotic arm assembly utilizes a gripper assembly to selective engage and retain the one or more objects. For example, the gripper assembly can utilize vacuum acquisition end effectors or a finger gripping type of tool to secure the object. Unfortunately, these types of gripper assemblies are unable to securely grasp a wide variety of different sized and shaped objects, and/or these types of gripper assemblies subject the object to excessive stress such as to damage the object being gripped. Accordingly, there is a need for an improved gripper assembly.

SUMMARY

[0003] A gripper assembly for selectively gripping an object includes a first gripper subassembly having a first elastic member, and a first deformer assembly that urges a first gripper fluid against the first elastic member to deform the first elastic member and form one or more first protrusions that engage the object. In one embodiment, the first deformer assembly urges the first gripper fluid against the first elastic member to deform the first elastic member and form a plurality of spaced apart, first protrusions that engage

the object. With this design, the gripper assembly generates a number of contact points spread around the object that readily conform to various shapes and sizes of the object, and the protrusions have a relatively large, collective frictional contact area. By spreading out contact points around the object, the gripper assembly can reduce contact stress on the body of the object, and increase stability during the gripping motion. This allows the gripper assembly to grip a wide variety of different objects without damaging the objects.

[0004] The first gripper subassembly can include a first gripper frame that engages the first elastic member. In this embodiment, the gripper frame includes a frame aperture and the first protrusion extends through the gripper frame and engages the object. In another embodiment, the gripper frame includes a plurality of spaced apart frame apertures, and the first gripper fluid against the first elastic member deforms the first elastic member and forms a plurality of first protrusions that engage the object, with each first protrusion extending through the gripper frame.

[0005] In one embodiment, the first elastic member forms an elastic chamber that encloses the first gripper fluid, and the first deformer assembly selectively deforms the elastic chamber to selectively create the first protrusions. The first deformer assembly can include an actuator for selectively deforming the elastic chamber. Further, the actuator can be pneumatic.

[0006] In certain embodiments, the first gripper fluid is substantially incompressible. For example, the first gripper fluid can be a viscous gel.

[0007] Additionally, the gripper assembly can include a second gripper subassembly that includes a second elastic member; and a second deformer assembly that urges a second gripper fluid against the second elastic member to deform the second elastic member and form at least one, second protrusion that engages the object spaced apart from the at least one, first protrusion.

[0008] Additionally, a robotic arm assembly that includes the gripper assembly and a robotic arm that moves and positions the gripper assembly is described herein.

[0009] In another embodiment, the gripper assembly includes (i) a first gripper subassembly that includes a first elastic member; and a first deformer assembly that urges a first gripper fluid against the first elastic member to deform the first elastic member and form a plurality of spaced apart first protrusions that engage the object; and (ii) a

second gripper subassembly that includes a second elastic member; and a second deformer assembly that urges a second gripper fluid against the second elastic member to deform the second elastic member and form a plurality of spaced apart second protrusions that engage the object. The second protrusions and the first protrusions are resilient and can be positioned on substantially opposite sides of the object.

[0010] In certain embodiments, one or both of the gripper subassemblies can include a gripper frame that engages the respective elastic member, and the gripper frame includes a plurality of spaced apart frame apertures. In this embodiment, the gripper fluid against the elastic member deforms the elastic member and forms a plurality of resilient protrusions that engage the object. Further, each protrusion extends through the gripper frame.

[0011] In certain embodiments, the elastic member of one or both of the gripper subassemblies can form an elastic gripper chamber that encloses the respective gripper fluid, and the deformer assembly can include an actuator that selectively deforms the gripper chamber to selectively create the plurality of protrusions.

[0012] In another embodiment, a method for selectively gripping an object includes (i) providing a first gripper subassembly that includes a first elastic member; and (ii) urging a first gripper fluid against the first elastic member to deform the first elastic member and form a plurality of spaced apart first protrusions that engage the object. The first elastic member can form an elastic gripper chamber that encloses the first gripper fluid, and an actuator can be used to deform the elastic gripper chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Figure 1 is a simplified side illustration of a robotic arm assembly that includes a gripper assembly having features of one embodiment, and an object that is gripped with the robotic arm assembly;

[0014] Figure 2A is a perspective view of the gripper assembly of Figure 1 in a retracted position;

[0015] Figure 2B is a side view of a portion of the gripper assembly of Figure 2A;

[0016] Figure 2C is a cut-away view of the portion of the gripper assembly of Figure 2B;

[0017] Figure 2D is a side view of a portion of the gripper assembly of Figure 2A in an extended position;

[0018] Figure 2E is a cut-away view of the portion of the gripper assembly of Figure 2D;

[0019] Figures 3A and 3B are simplified side views of another embodiment of the gripper assembly;

[0020] Figures 4A and 4B are simplified cut-away views of a gripper subassembly;

[0021] Figures 5A and 5B are simplified cut-away views of another embodiment of a gripper subassembly;

[0022] Figures 6A and 6B are simplified cut-away views of yet another embodiment of a gripper subassembly;

[0023] Figures 7A and 7B are simplified cut-away views of still another embodiment of a gripper subassembly;

[0024] Figure 8 is a simplified side view of yet another embodiment of the gripper assembly and

[0025] Figure 9 is a simplified side illustration of a robotic arm assembly that includes a gripper assembly having features of another embodiment, and an object that is gripped with the robotic arm assembly.

DETAILED DESCRIPTION

[0026] An embodiment of a robotic arm assembly 10 that is used to grip and move one or more objects 12 is illustrated in Figure 1. In this embodiment, the robotic arm assembly 10 includes a robotic arm 14, a gripper assembly 16, and a control system 18 that cooperate to grip and move one or more objects 12. As an overview, the gripper assembly 16 is uniquely designed to be a universal gripper that can securely grip many different objects 12 of various shapes and sizes with minimum contact stresses. In certain embodiments, the gripper assembly 16 is uniquely designed to have a number of contact points spread around the object 12 that readily conform to various shapes and sizes of the object 12, and have a relatively large, collective frictional contact area. By spreading out contact points around the object 12, the gripper assembly 16 can reduce contact stress on the body of the object 12, and increase stability during the gripping motion. This allows the robotic arm assembly 10 to grip and move a wide variety of different objects

12 without damaging the objects 12. Moreover, the gripper assembly 16 is energy efficient, and relatively easy and inexpensive to make with readily available material.

[0027] The type of objects 12 (only one is illustrated in Figure 1) that can be gripped and moved by the robotic arm assembly 10 can be varied. In the simplified example in Figure 1, the object 12 is a piece of fruit, e.g. an apple. In this embodiment, the object 12 is irregular shaped. Alternatively, for example, the object 12 can be cylindrical shaped (e.g. a can of soda or a bottle of water), cone shaped (e.g. a funnel), rectangular shaped (e.g. a brick), or some other shape. As non-exclusive examples, the object 12 can be one or more parts, components, devices, products, or other types of objects 12.

[0028] Some of the Figures provided herein include an orientation system that designates an X axis, a Y axis that is orthogonal to the X axis, and a Z axis that is orthogonal to the X and Y axes. In these Figures, the Z axis is oriented in the vertical direction. It should be understood that the orientation system is merely for reference and can be varied. For example, the X axis can be switched with the Y axis and/or the stage assembly 10 can be rotated. Moreover, it should be noted that any of these axes can also be referred to as a first, a second, and/or a third axis.

[0029] In Figure 1, the robotic arm 14 is secured to a mounting base 20, and the object 12 is positioned on a pedestal 22 that is supported by the mounting base 20. Alternatively, the robotic arm 14 can be attached to another structure (not shown) and/or the object 12 positioned at another location.

[0030] In the non-exclusive embodiment illustrated in Figure 1, the robotic arm 14 is a mechanical arm that can be controlled to securely grip the object 12, and move the object 12 along one or more of the axes, and about one or more axes. The robotic arm 14 can includes an arm mount 14A, one or more links 14B connected by joints 14C, and one or more actuators 14D (illustrated in phantom) that are controlled to move and position the gripper assembly 16. In Figure 1, the gripper assembly 16 is secured to a distal end 14E of the robotic arm 14.

[0031] Alternatively, the robotic arm 14 can have a design that is much different than illustrated in Figure 1, or the gripper assembly 16 can be used as part of another type of assembly. For example, the robotic arm 14 can be part of a larger robot, a manufacturing tool, a packaging tool, and/or an assembly tool.

[0032] The control system 18 can control the components of the robotic arm assembly 10, such as the actuators 14D and the gripper assembly 16. As a non-exclusive example, the control system 18 can include one or more processors 18A (illustrated as a box), and one or more electronic storage devices 18B (illustrated as a box). In Figure 1, the control system 18 is illustrated as a single system. Alternatively, the control system 18 can be a distributed computer system.

[0033] The design of the gripper assembly 16 can be varied according to the teachings provided herein. In one, non-exclusive embodiment, the gripper assembly 16 includes one or more gripper subassemblies that grip the object 12. In Figure 1, the gripper assembly 16 includes two gripper subassemblies, namely a first gripper subassembly 24 and a second gripper subassembly 26 that are illustrated in an extended position 28 in which the gripper subassemblies 24, 26 engage and secure the object 12. The extended position 28 can also be referred to as the engaged position.

[0034] In the embodiment illustrated in Figure 1, the gripper subassemblies 24, 26 are spaced apart and positioned on substantially opposite sides of the object 12. As used herein, "substantially opposite" shall mean approximately one-hundred and eighty degrees apart.

[0035] Moreover, in Figure 1, (i) the first gripper subassembly 24 includes a first elastic member 24A that is selectively deformed with a first gripper fluid 24B (illustrated with small circles in phantom) to form one or more first protrusions 24C that contact the object 12; and (ii) the second gripper subassembly 26 includes a second elastic member 26A that is selectively deformed with a second gripper fluid 26B (illustrated with small circles in phantom) to form one or more second protrusions 26C that contact the object 12.

[0036] Each protrusion 24C, 26C can be shaped similar to a balloon and can be resilient, pliable, a little springy, and flexible. With this design, the gripper assembly 16 has a number contact points spread around the object 12 that readily conform to various shapes and sizes of the object 12, and the protrusions 24C, 26C have a relatively large, collective frictional contact area. Stated in another fashion, with this design, the elastic members 24A, 26A are pressurized to create protrusions 24C, 26C that contact the object 12 to be grasped from two opposing sides. Thus, the protrusions 24C, 26C can contact the object

12 and conform to its shape, and achieve the gripping force by means of friction and geometry interlocking.

[0037] Further, as provided in more detail below, a length of the protrusions 24C, 26C can be precisely controlled to allow for the picking up of a wide variety of objects 12 having various sizes and precisely adjusting the contact forces on the object 12. Moreover, a stiffness of the protrusions 24C, 26C can be precisely controlled to allow for the picking up of fragile objects 12 or objects of various sizes and shapes.

[0038] In the non-exclusive embodiment illustrated in Figure 1, the gripper assembly 16 also includes one or more deformation assemblies 30 (illustrated as a box) that can be controlled (e,g, by the control system 18) to control (i) the pressure of the first gripper fluid 24B against the first elastic member 24A to control the characteristics of the first protrusions 24C, and (ii) the pressure of the second gripper fluid 26B against the second elastic member 26A to control the characteristics of the second protrusions 26C.

[0039] Figure 2A is a perspective view of the gripper assembly 16 of Figure 1 including the gripper subassemblies 24, 26 and the deformation assembly 30. In Figure 2A, the gripper subassemblies 24, 26 are illustrated in a retracted position 32 in which the gripper assembly 16 does not engage the object 12 (illustrated in Figure 1). Further, Figure 2B is a side view and Figure 2C is a cut-away view of a portion of the gripper assembly 16 of Figure 2A in the retracted position 32.

[0040] With reference to Figures 2A-2C, in this embodiment, the gripper assembly 16 also includes a gripper mount 34 that retains and maintains the first gripper subassembly 24 spaced apart a gripper separation distance 36 from the second gripper subassembly 26. With this design, the size of the gripper separation distance 36 can be changed by changing the design of the gripper mount 34. It should be noted that the required size of the gripper separation distance 36 will vary according to the range of sizes of the objects 12 (illustrated in Figure 1) desired to be picked up with the gripper assembly 16, and the design of the gripper assembly 16. In alternative, non-exclusive examples, the typical gripper assembly 16 can be designed to have a gripper separation distance 36 of approximately 5 to 75 millimeters. However, it should be noted other values for the gripper separation distance 36 can be utilized. Further, as detailed below, the size of the gripper separation distance 36 can be selectively adjustable in certain designs.

[0041] In one non-exclusive embodiment, the gripper mount 34 is rigid and includes a crossbeam 34A, a first flange 34B that cantilevers downward from one end of the crossbeam 34A, and a second flange 34C that cantilevers downward from the opposite end of the crossbeam 34A. In this embodiment, (i) the first gripper subassembly 24 is attached to the first flange 34B and cantilevers downward from the first flange 34B, and (ii) the second gripper subassembly 26 is fixed to the second flange 34C and cantilevers downward from the second flange 34C. Further, the gripper mount 34 maintains the gripper subassemblies 24, 26 substantially parallel to each other.

[0042] The design of each gripper subassembly 24, 26 can be varied pursuant to the teachings provided herein. In Figures 2A-2C, the first gripper subassembly 24 and the second gripper subassembly 26 are similar in design. Alternatively, the first gripper subassembly 24 can be designed to be different than the second gripper subassembly 26.

[0043] In one embodiment, (i) the first gripper subassembly 24 includes the first elastic member 24A, the first gripper fluid 24B (illustrated as small circles), a first gripper frame 24D, and a first deformer assembly 24E; and (i) the second gripper subassembly 26 includes the second elastic member 26A, the second gripper fluid 26B (illustrated as small circles), a second gripper frame 26D, and a second deformer assembly 26E. The design of each of these components can be varied pursuant to the teachings provided herein to adjust the characteristics of the gripper assembly 16.

[0044] The elasticity of each elastic member 24A, 26A can be selected to achieve the desired performance of the gripper assembly 16. In one embodiment, each elastic member 24A, 26A is be a hyperelastic membrane. In alternative, non-exclusive embodiments, one or both elastic members 24A, 26A have a maximum strain limit of at least 50% or more. In alternative, non-exclusive embodiments, one or both elastic members 24A, 26A has an elasticity of at least 0.001, 0.01, 0.05, or 0.1 GPa. Non-exclusive examples of suitable materials for one or both elastic members 24A, 26A include elastomers, polyurethane, latex, or silicone.

[0045] In the embodiment illustrated in Figure 2C, the first elastic member 24A is shaped similar to a hollow ball that is forced against the first gripper frame 24D. With this design, the first elastic member 24A forms a first gripper chamber 24F that fully encloses the first

gripper fluid 24B. Further, the second elastic member 26A can be shaped similar to a hollow ball that is forced against the second gripper frame 26D. With this design, the second elastic member 26A forms a second gripper chamber 26F that fully encloses the second gripper fluid 26B. In this embodiment, the first gripper fluid 24B is separated from the other components and encapsulated with the first elastic member 24A, and the second gripper fluid 26B is separated from the other components and encapsulated with the second elastic member 26A.

[0046] It should be noted that the first elastic member 24A forms the resilient first protrusions 24C that engage the object 12, and the second elastic member 26A forms the resilient second protrusions 26C that engage the object 12. Thus, the material for the elastic members 24C, 26C can be selected to be slightly tacky to improve the gripping of the object 12.

[0047] As alternative, non-exclusive examples, each elastic member 24A, 26A can have a diameter of at least 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, or 200 millimeters prior to deformation. Stated in a different fashion, as alternative, non-exclusive examples, each elastic member 24A, 26A can be sized and shaped to retain at least 0.05, 0.1, 0.2, 0.5, or 1 liter of gripper fluid 24B, 26B.

[0048] It should be noted that the thickness of each elastic member 24A, 26A can be varied to adjust the performance of the gripper assembly 16. As non-exclusive examples, each elastic member 24A, 26A can have a thickness of at least 0.1, 0.5, 1 or 2 millimeters.

[0049] In Figure 2C, the first elastic member 24A is secured to an inner side 24G of the first gripper frame 24D, and the second elastic member 26A is secured to an inner side 26G of the second gripper frame 26D.

[0050] Alternatively, each elastic member 24A, 26A can have a different configuration than illustrated in Figure 2C.

[0051] The first gripper fluid 24B engages the first elastic member 24A, and the second gripper fluid 26B engages the second elastic member 26A. In one embodiment, one or both of the gripper fluids 24B, 26B has a relatively high viscosity. The viscosity of the fluid 24B, 26B can be selected to achieve the desired performance of the gripper assembly 16, including the resiliency of the protrusions 24C, 26C. Generally speaking, as the viscosity increases, the stiffness of the protrusions 24C, 26C can be increased.

As alternative, non-exclusive embodiments, relatively high viscosity shall mean a viscosity of at least 1, 100, 1000, 10000, or 100000 cP.

[0052] Further, one or both of the gripper fluids 24B, 26B can be substantially incompressible. As used herein the term substantially incompressible shall mean the density of the fluid can't change by more than 5% under pressure.

[0053] Non-exclusive examples of suitable gripper fluids 24B, 26B include a viscous gel or a viscous slime, liquid silicone, polymeric glue solution, grease, oil, or water.

[0054] The first gripper frame 24D retains the first elastic member 24A, and the second gripper frame 26D retains the second elastic member 26A. In the embodiment illustrated in Figures 2A-2C, (i) the first gripper frame 24D is generally rectangular plate shaped and includes one or more, round, first frame apertures 24H that extend transversely through the first gripper frame 24D; and (ii) the second gripper frame 26D is generally rectangular plate shaped and includes one or more, round, second frame apertures 26H that extend transversely through the second gripper frame 26D. Alternatively, each gripper frame 24D, 26D can have another shape, and/or each frame aperture 24H, 26H can have another shape.

[0055] The number of first frame apertures 24H corresponds to the number of first protrusions 24C (illustrated in Figure 1), and the number of second frame apertures 26H corresponds to the number of second protrusions 26C (illustrated in Figure 1). Further, the performance characteristics of the gripper assembly 16 can be influenced by the number frame apertures 24H, 26H, the size and shape of each frame apertures 24H, 26H, and the pattern of frame apertures 24H, 26H.

[0056] In the non-exclusive embodiment illustrated in Figures 2A and 2C, each first gripper frame 24D includes nineteen spaced apart first frame apertures 24H organized in a staggered pattern, and each second gripper frame 26D includes nineteen spaced apart second frame apertures 26H organized in a staggered pattern. With this design, the first gripper subassembly 24 can create an array of nineteen spaced apart first protrusions 24C, and the second gripper subassembly 26 can create an array of nineteen spaced apart second protrusions 26C. Alternatively, the first gripper frame 24D can include more than nineteen first frame apertures 24H to create more than nineteen first protrusions 24C or fewer than nineteen first frame apertures 24H to create fewer than nineteen first

protrusions 24C. Similarly, the second gripper frame 26D can include more than nineteen second frame apertures 26H to create more than nineteen second protrusions 26C or fewer than nineteen second frame apertures 26H to create fewer than nineteen second protrusions 26C.

[0057] Alternatively, the pattern of apertures 24H, 26H can be different than that illustrated in the Figures. For example, the apertures 24H, 26H can be organized in a circular or rectangular pattern.

[0058] As alternative, non-exclusive examples, each of the apertures 24H, 26H can have diameter of at least 5, 10, 20, or 50 millimeters.

[0059] The first deformer assembly 24E urges the first gripper fluid 24B against the first elastic member 24A to deform the first elastic member 24A and form the first protrusions 24C that engage the object 12. In one embodiment, the first deformer assembly 24E includes a tubular shaped, first housing 24I and a first, back plate 24J. In this embodiment, the first housing 24I extends between the first gripper frame 24D and the first back plate 24J, and these components cooperate to encircle the first elastic member 24A and form a first deformer chamber 24K adjacent to (and behind) the first elastic member 24A.

[0060] Similarly, the second deformer assembly 26E urges the second gripper fluid 26B against the second elastic member 26A to deform the second elastic member 26A and form the second protrusions 26C that engage the object 12. In one embodiment, the second deformer assembly 26E includes a tubular shaped, second housing 26I and a second, back plate 26J. In this embodiment, the second housing 26I extends between the second gripper frame 26D and the second back plate 26J, and these components cooperate to encircle the second elastic member 26A and form a second deformer chamber 26K adjacent to (and behind) the second elastic member 26A.

[0061] In one embodiment, (i) the first deformer assembly 24E includes a first inlet port 24L that connects the deformation assembly 30 (illustrated in Figure 2A) in fluid communication with the first deformer chamber 24K; and (ii) the second deformer assembly 26E includes a second inlet port 26L that connects the deformation assembly 30 (illustrated in Figure 2A) in fluid communication with the second deformer chamber 26K. Further, the deformation assembly 30 can include one or more fluid sources (not

shown) that (i) selectively pumps a deformation fluid 38 (illustrated as small squares) into the first deformer chamber 24K to selectively deform the first elastic member 24A to selectively create the first protrusions 24C; and (ii) selectively pumps the deformation fluid 38 (illustrated as small squares) into the second deformer chamber 26K to selectively deform the second elastic member 26A to selectively create the second protrusions 26C.

[0062] The type of deformation fluid 38 utilized can be varied. Non-exclusive examples of suitable deformation fluids 38 include air, water, oil, or other mixtures.

[0063] With this design, the deformation assembly 30 cooperates with the first deformer assembly 24E to create an actuator that controls the pressure in the first gripper chamber 24F to control the size, shape and stiffness of the first protrusions 24C. Similarly, the deformation assembly 30 cooperates with the second deformer assembly 26E to create an actuator that controls the pressure in the second gripper chamber 26F to control the size, shape and stiffness of the second protrusions 26C. If the deformation fluid 38 is air or another gas, each actuator is a pneumatic actuator. Alternatively, each actuator can include a motor or other type of actuator.

[0064] Figure 2D is a side view of a portion of the gripper assembly 16 of Figure 2A in the extended position 28, and Figure 2E is a cut-away view of the portion of the gripper assembly 16 from Figure 2D including the gripper subassemblies 24, 26. Figure 2D also references the first elastic member 24A, the first gripper fluid 24B (illustrated with dashed circles), the first protrusions 24C, the second elastic member 26A, the second gripper fluid 24B (illustrated with dashed circles), and the second protrusions 26C. Further, Figure 2E also references the first elastic member 24A, the first gripper fluid 24B (small circles), the first protrusions 24C, the first gripper frame 24D, the first frame apertures 24H, the first deformer chamber 24K, the second elastic member 26A, the second gripper fluid 26B (small circles), the second protrusions 26C, the second gripper frame 26D, the second frame apertures 26H, and the second deformer chamber 26K.

[0065] With reference to Figures 2A, 2C and 2E, in one embodiment, the deformation assembly 30 directs the deformation fluid 38 into each deformer chamber 24K, 26K concurrently to concurrently create the protrusions 24C, 26C. With this design, the characteristics (e.g. length and stiffness) of the protrusions 24C, 26C can be adjusted by adjusting the pressure in each deformer chamber 24K, 26K.

[0066] Alternatively, the deformation assembly 30 can independently direct the deformation fluid 38 into each deformer chamber 24K, 26K to independently create the set of first protrusions 24C and the set of second protrusions 26C. It should be noted that with independent control, the characteristics (e.g. length and stiffness) of each set of the protrusions 24C, 26C can be adjusted by adjusting the pressure in the respective deformer chamber 24K, 26K.

[0067] It should be noted that the deformation assembly 30 can be controlled by the control system 18 (illustrated in Figure 1) to selectively move the gripper assembly 16 between the retracted position 32 and the extended position 28. Further, the size and/or stiffness of each protrusion 24C, 26C can be controlled by controlling the pressure in the respective deformer chamber 24K, 26K. In alternative, non-exclusive examples, the deformation assembly 30 controls the pressure in the deformer chambers 24K, 26K to be at least 10, 15, 20, 25, 30, 40, or 50 kPa during the creation of the protrusions 24C, 26C.

[0068] With the present design, the deformation fluid 38 injected into the first deformer chamber 24K (i) increases the pressure in the first deformer chamber 24K, (ii) deforms the first gripper chamber 24F, (iii) increases the pressure in the first gripper chamber 24F, and (iv) causes the first gripper fluid 24B to deform the first elastic member 24A to protrude through the first frame apertures 24H of the first gripper frame 24D to form an array of the first protrusions 24C. Thus, the force created within the first deformer chamber 24K is transferred via the first gripper fluid 24B to the first elastic member 24A.

[0069] Similarly, the deformation fluid 38 injected into the second deformer chamber 26K (i) increases the pressure in the second deformer chamber 26K, (ii) deforms the second gripper chamber 26F, (iii) increases the pressure in the second gripper chamber 26F, and (iv) causes the second gripper fluid 26B to deform the second elastic member 26A to protrude through the second frame apertures 26H of the second gripper frame 26D to form an array of the second protrusions 26C. Thus, the force created within the second deformer chamber 26K is transferred via the second gripper fluid 26B to the second elastic member 26A.

[0070] It should be noted that the viscosity of the first gripper fluid 24B will influence how the force is transferred to the first elastic member 24A, and the viscosity of the second gripper fluid 26B will influence how the force is transferred to the second elastic member

26A. Generally, if the first gripper fluid 24B is sufficiently viscous, the force created within the first deformer chamber 24K will be uniformly transferred to the first elastic member 24A and the first protrusions 24C will each be very similar in size and shape. Similarly, if the second gripper fluid 26B is sufficiently viscous, the force created within the second deformer chamber 26K will be uniformly transferred to the second elastic member 26A and the second protrusions 26C will each be very similar in size and shape. Alternatively, if the gripper fluid 24B, 26B is not sufficiently viscous, the size of the protrusions 24C, 26C may not be uniform.

[0071] Moreover, as viscosity of the gripper fluids 24B, 26B will influence the stiffness of the respective protrusions 24C, 26C. Generally, as the viscosity is increased, the stiffness of the protrusions 24C, 26C will increase to influence gripping.

[0072] Each protrusion 24C, 26C has a protrusion length 40 and a protrusion width 42. In one embodiment, the protrusion length 40 and protrusion width 42 of each protrusion 24C, 26C is approximately the same. Alternatively, the gripper assembly 16 can be designed so that the protrusion length 40 and/or protrusion width 42 of one or more of the protrusion 24C, 26C is different. As alternative, non-exclusive examples, each protrusion 24C, 26C (i) can have a protrusion length 40 of at least 1, 5, 10, 15, 20, or 25 millimeters; (ii) can have a protrusion width 42 of at least 1, 5, 10, 15, 30, or 50 millimeters; and (iii) each protrusion 24C, 26C can have a stiffness of at least 0.1 N/mm.

[0073] It should be noted that in this embodiment, each first protrusion 24C extends completely through a corresponding first frame aperture 24H in the first gripper frame 24D, and each second protrusion 26C extends completely through a corresponding second frame aperture 26H in the second gripper frame 26D.

[0074] The parameters which can affect the characteristics of the protrusions 24C, 26 and the performance of the gripper assembly 16 include (i) the aperture 24H, 26H size, (ii) the aperture 24H, 26H pattern, (iii) the actuation pressure within the deformer chambers 24K, 26K, (iv) the thickness and material of each elastic member 24A, 26A, (v) and the properties of the gripper fluid 24B, 26B. As a result thereof, the gripper assembly 16 can be designed to have relatively long, resilient protrusions 24C, 26C so that the gripper assembly 16 can be used to grip a wide range of different objects 12 of different sizes.

[0075] It should be noted that the actuation time and the pressure release time of the deformation assembly 30 can be adjusted to adjust the performance of the gripper assembly 16. In certain embodiments, when the pressure is decreased in the deformer chambers 24K, 26K, the respective elastic member 24A, 26A will return to the previous configuration without the protrusions 24C, 26C. In one embodiment, the deformation assembly 30 can be controlled to create a vacuum in the respective deformer chambers 24K, 26K to quickly move the gripper assembly 16 from the extended position 28 to the retracted position 32 to reduce gripping cycle time.

[0076] It should also be noted that (i) the first protrusions 24C are all spaced apart from each other, (ii) the second protrusions 26C are all spaced apart from each other, (iii) the first protrusions 24C are all spaced apart from second protrusions 26C, and (iv) the first protrusions 24C are positioned on the opposite side of the object 12 from second protrusions 26C.

[0077] With the present design, the gripper assembly 16 includes elastic members 24A, 26A that are pressurized to create the protrusions 24C, 26C (the shape of balloons) to contact the object 12 to be grasped from two opposing sides. The protrusions 24C, 26C that contact the object 12 conform to its shape and achieve the gripping force by means of friction and geometry interlocking. Thus, the problem of securing different objects 12 of various shapes and sizes with minimum contact stresses is solved by a universal gripper assembly 16, which can be actuated to generate gripping force via the gripper fluid 24B, 26B encapsulated in elastic members 24A, 26A.

[0078] The array of first protrusions 24C can be constructed by placing the first elastic member 24A behind the perforated first gripper frame 24D, and subsequently deforming the first elastic member 24A with the first gripper fluid 24B. Similarly, the array of second protrusions 26C can be constructed by placing the second elastic member 26A behind the perforated second gripper frame 26D, and subsequently deforming the second elastic member 26A with the second gripper fluid 26B.

[0079] Figures 3A and 3B are simplified side views of another embodiment of the gripper assembly 316 in the retracted position 332. In this embodiment, the gripper assembly 316 includes the first gripper subassembly 324 and the second gripper subassembly 326 that are somewhat similar to the corresponding components described above and

illustrated in Figures 1-2E. However, in this embodiment, the gripper mount 334 is slightly different.

[0080] More specifically, in the embodiment illustrated in Figures 3A and 3B, the gripper mount 334 includes (i) a first actuator/guide 344 that connects the first flange 334B and the first gripper subassembly 324 to the crossbeam 334A; and (ii) a second actuator/guide 346 that connects the second flange 334C and the second gripper subassembly 326 to the crossbeam 334A. With this design, the control system 18 (illustrated in Figure 1) can (i) control the first actuator/guide 344 to selectively move the first gripper subassembly 324 relative to the second gripper subassembly 326 along an axis (e.g. the Y axis); and (ii) control the second actuator/guide 346 to selectively move the second gripper subassembly 326 relative to the first gripper subassembly 324 along an axis (e.g. the Y axis).

[0081] As a result of this design, the actuator/guides 344, 346 can be controlled to selectively adjust the gripper separation distance to adjust for objects 12 (illustrated in Figure 1) having a wider range of sizes. Figure 3A illustrates the gripper subassemblies 324, 326 at a first gripper separation distance 336A, and Figure 3B illustrates the gripper subassemblies 324, 326 at a second gripper separation distance 336B that is different from the first gripper separation distance 336A.

[0082] For example, one or both of the actuator/guides 344, 346 can include a linear actuator and a linear guide. Alternatively, one or both of the actuator/guides 344, 346 can include a manual actuator, or another type of actuator.

[0083] In an alternative embodiment, the gripper assembly 316 can be designed with only one of the actuator/guides 344, 346.

[0084] Figures 4A and 4B are simplified cut-away views of another embodiment of a gripper subassembly 424 that can be used as the first gripper subassembly 24, 324 or the second gripper subassembly 26, 326 in the embodiments described above. In this embodiment, the gripper subassembly 424 includes an elastic member 424A, a gripper fluid 424B, a gripper frame 424D, that are similar to the corresponding components described above. However, in this embodiment, the deformer assembly 424E is different.

[0085] The deformer assembly 424E again compresses the gripper chamber 424F and urges the gripper fluid 424B against the elastic member 424A to deform the elastic

member 424A and form the protrusions 424C that extend through the frame apertures 424H and engage the object 12 (illustrated in Figure 1). In Figures 4A and 4B, the deformer assembly 424E includes a tubular shaped, housing 424I, a back plate 424J, a piston 450, and an actuator 452. In this embodiment, the housing 424I extends between the gripper frame 424D and the back plate 424J, and these components cooperate to encircle the elastic member 424A and form a deformer chamber 424K adjacent to (and behind) the elastic member 424A. However, in this embodiment, the piston 450 is positioned in the deformer chamber 424K and the actuator 452 moves the piston 450 linearly (e.g. along the Y axis) in the deformer chamber 424K to selectively deform the gripper chamber 424F to selectively create the protrusions 424C. As non-exclusive examples, the actuator 452 can be a linear motor, a rotary motor or another type of actuator.

[0086] Figures 5A and 5B are simplified cut-away views of another embodiment of a gripper subassembly 524 that can be used as the first gripper subassembly 24, 324 or the second gripper subassembly 26, 326 in the embodiments described above. In this embodiment, the gripper subassembly 524 includes an elastic member 524A, a gripper fluid 524B, a gripper frame 524D, that are similar to the corresponding components described above. However, in this embodiment, the deformer assembly 524E is different.

[0087] The deformer assembly 524E again compresses the gripper chamber 524F and urges the gripper fluid 524B against the elastic member 524A to deform the elastic member 524A and form the protrusions 524C that extend through the frame apertures 542H and engage the object 12 (illustrated in Figure 1). In Figures 5A and 5B, the deformer assembly 524E includes a tubular shaped, housing 524I, a back plate 524J, a piston 550, and an inlet port 524L. In this embodiment, the housing 524I extends between the gripper frame 524D and the back plate 524J, and these components cooperate to encircle the elastic member 524A and form a deformer chamber 524K adjacent to (and behind) the elastic member 524A. However, in this embodiment, the piston 550 is positioned in the deformer chamber 524K. In this embodiment, the deformation assembly 30 (illustrated in Figure 1) can direct the deformation fluid 538 into the deformer chamber 524K to move the piston 550 linearly (e.g. along the Y axis) in the deformer chamber

524K to selectively deform the gripper chamber 524F to selectively create the protrusions 524C.

[0088] Figures 6A and 6B are simplified cut-away views of yet another embodiment of a gripper subassembly 624 that can be used as the first gripper subassembly 24, 324 or the second gripper subassembly 26, 326 in the embodiments described above. In this embodiment, the gripper subassembly 624 includes a gripper fluid 624B, a gripper frame 624D, that are similar to the corresponding components described above. However, in this embodiment, an elastic member 624A, and a deformer assembly 624E are slightly different.

[0089] More specifically, in this embodiment, the elastic member 624A is not a ball that encloses the gripper fluid 624B. Instead, the elastic member 624A is a flat sheet that is attached to the gripper frame 624D. In this embodiment, the elastic member 624A, a housing 624I and a piston 650 cooperated to define the gripper chamber 624F that encloses the gripper fluid 624B.

[0090] Further, in this embodiment, the deformer assembly 624E again compresses the gripper chamber 624F and urges the gripper fluid 624B against the elastic member 624A to deform the elastic member 624A and form the protrusions 624C that extend through the frame apertures 624H and engage the object 12 (illustrated in Figure 1). In Figures 6A and 6B, the deformer assembly 624E includes the tubular shaped, housing 624I, a back plate 624J, the piston 650, and an actuator 652. In this embodiment, the housing 624I extends between the gripper frame 624D and the back plate 624J, and these components cooperate to encircle the elastic member 624A and form a deformer chamber 624K adjacent to (and behind) the elastic member 624A.

[0091] However, in this embodiment, the piston 650 separates the gripper chamber 624F from the deformer chamber 624K and the actuator 652 moves the piston 650 linearly (e.g. along the Y axis) in the deformer chamber 624K to selectively compress the gripper chamber 624F to selectively create the protrusions 624C. As non-exclusive examples, the actuator 652 can be a linear motor, a pneumatic actuator, a rotary motor or another type of actuator.

[0092] Alternatively, the deformation assembly 30 (illustrated in Figure 1) can direct a deformation fluid (not shown in Figures 6A and 6B) in the deformer chamber 624K behind the piston 650 to selectively move the piston 650 and generate the protrusions 624C.

[0093] Figures 7A and 7B are simplified cut-away views of still another embodiment of a gripper subassembly 724 that can be used as the first gripper subassembly 24, 324 or the second gripper subassembly 26, 326 in the embodiments described above. In this embodiment, the gripper subassembly 724 includes an elastic member 724A, a gripper fluid 724B, a gripper frame 724D, that are similar to the corresponding components described above. However, in this embodiment, the deformer assembly 724E is different.

[0094] The deformer assembly 724E again compresses the gripper chamber 724F and urges the gripper fluid 724B against the elastic member 724A to deform the elastic member 724A and form the protrusions 724C that extend through the frame apertures 742H and engage the object 12 (illustrated in Figure 1). In Figures 7A and 7B, the deformer assembly 724E includes a tubular shaped, housing 724I, a back plate 724J, and an inflatable bladder 754. In this embodiment, the housing 724I extends between the gripper frame 724D and the back plate 724J, and these components cooperate to encircle the elastic member 724A and form a deformer chamber 724K adjacent to (and behind) the elastic member 724A. However, in this embodiment, the inflatable bladder 754 is positioned in the deformer chamber 724K. In this embodiment, the deformation assembly 30 (illustrated in Figure 1) can direct the deformation fluid 738 into the bladder 754 to selectively deform the gripper chamber 724F to selectively create the protrusions 724C.

[0095] In the nonexclusive embodiment illustrated in Figures 7A and 7B, the inflatable bladder 754 is shaped somewhat similar to an inner tube. Alternatively, the bladder 754 can have another shape, such as a ball or shape.

[0096] Figure 8 is a simplified side view of yet another embodiment of the gripper assembly 816 that is somewhat similar to the corresponding gripper assemblies 16, 316 described above. In this embodiment, the gripper assembly 816 includes more than two, e.g. four gripper subassemblies. More specifically, the gripper assembly 816 includes a first gripper subassembly 824, a second gripper subassembly 826, a third gripper subassembly 854, and a fourth gripper subassembly (not shown in Figure 8) that are

secured to the . In this embodiment, each gripper subassembly 824, 826, 854 can be similar to any of the gripper subassemblies described above.

[0097] In Figure 8, the four gripper subassembly 824, 826, 854 surround and engage the object 12 (illustrated in Figure 1). Alternatively, the gripper assembly 816 can be designed to have more than four or fewer than four gripper subassemblies 824, 826, 854.

[0098] Figure 9 is a simplified side illustration of another embodiment of a robotic arm assembly 910 that is used to grip and move one or more objects 12. In this embodiment, the robotic arm assembly 910 includes a robotic arm 914, a gripper assembly 916, and a control system 918 that cooperate to grip and move one or more objects 12. In this embodiment, the robotic arm 914, and the control system 918 are similar to the corresponding components described above and illustrated in Figure 1. However, in Figure 9, the gripper assembly 916 is slightly different.

[0099] More specifically, in Figure 9, the gripper assembly 916 is again uniquely designed to be a universal gripper that can securely grip many different objects 12 of various shapes and sizes with minimum contact stresses. In certain embodiments, the gripper assembly 916 is uniquely designed to have a number of contact points spread around the object 12 that readily conform to various shapes and sizes of the object 12, and have a relatively large, collective frictional contact area.

[0100] In Figure 9, the gripper assembly 916 includes the first gripper subassembly 924 and the second gripper subassembly 926 that are somewhat similar to the corresponding components described above and illustrated in Figures 3A and 3B. More specifically, in the embodiment illustrated in Figure 9, the gripper mount 934 includes (i) a first actuator/guide 944 that connects the first flange 934B and the first gripper subassembly 924 to the crossbeam 934A; and (ii) a second actuator/guide 946 that connects the second flange 934C and the second gripper subassembly 926 to the crossbeam 934A. With this design, the control system 918 can (i) control the first actuator/guide 944 to selectively move the first gripper subassembly 924 relative to the second gripper subassembly 926 along an axis (e.g. the Y axis); and (ii) control the second actuator/guide 946 to selectively move the second gripper subassembly 926 relative to the first gripper subassembly 924 along an axis (e.g. the Y axis).

[0101] As a result of this design, the actuator/guides 944, 946 can be controlled to selectively adjust the gripper separation distance to adjust for objects 12 (illustrated in Figure 1) having a wider range of sizes.

[0102] Alternatively, it should be noted that any of the gripper assemblies disclosed herein can be incorporated into any prior art type gripper.

[0103] While a number of exemplary aspects and embodiments of the gripper assembly have been discussed above, those of skill in the art will recognize certain modifications, permutations, additions and sub-combinations thereof. It is therefore intended that the following appended claims and claims hereafter introduced are interpreted to include all such modifications, permutations, additions and sub-combinations as are within their true spirit and scope.

What is claimed is:

1. A gripper assembly for selectively gripping an object, the gripper assembly comprising:

a first gripper subassembly that includes a first elastic member; and a first deformer assembly that urges a first gripper fluid against the first elastic member to deform the first elastic member and form at least one, first protrusion that engages the object.

2. The gripper assembly of claim 1 wherein the first deformer assembly urges the first gripper fluid against the first elastic member to deform the first elastic member and form a plurality of spaced apart, first protrusions that engage the object.

3. The gripper assembly of claim 1 wherein the first gripper subassembly includes a first gripper frame that engages the first elastic member, and wherein the first gripper frame includes a first frame aperture and the first protrusion extends through the gripper frame and engages the object.

4. The gripper assembly of claim 1 wherein the first gripper subassembly includes a gripper frame that engages the first elastic member, wherein the gripper frame includes a plurality of spaced apart frame apertures, and the first gripper fluid against the first elastic member deforms the first elastic member and forms a plurality of first protrusions that engage the object, wherein each first protrusion extends through the gripper frame.

5. The gripper assembly of claim 1 wherein the first elastic member forms an elastic gripper chamber that encloses the first gripper fluid, and the first deformer assembly selectively deforms the gripper chamber to selectively create the first protrusion.

6. The gripper assembly of claim 5 wherein the first deformer assembly includes an actuator for selectively deforming the gripper chamber.

7. The gripper assembly of claim 6 wherein the actuator is pnuematic.

8. The gripper assembly of claim 1 wherein the first gripper fluid is substantially incompressible.

9. The gripper assembly of claim 1 wherein the first gripper fluid is a viscous gel.

10. The gripper assembly of claim 1 further comprising a second gripper subassembly that includes a second elastic member; and a second deformer assembly that urges a second gripper fluid against the second elastic member to deform the second elastic member and form at least one, second protrusion that engages the object spaced apart from the at least one, first protrusion.

11. A robotic arm assembly that includes the gripper assembly of claim 1 and a robotic arm that moves and positions the gripper assembly.

12. A gripper assembly for selectively gripping an object, the gripper assembly comprising:

a first gripper subassembly that includes a first elastic member; and a first deformer assembly that urges a first gripper fluid against the first elastic member to deform the first elastic member and form a plurality of spaced apart first protrusions that engage the object; and

a second gripper subassembly that includes a second elastic member; and a second deformer assembly that urges a second gripper fluid against the second elastic member to deform the second elastic member and form a plurality of spaced apart second protrusions that engage the object, wherein the second protrusions and the first protrusions are positioned on substantially opposite sides of the object.

13. The gripper assembly of claim 12 wherein the first gripper subassembly includes a gripper frame that engages the first elastic member, and wherein the gripper frame includes a plurality of spaced apart frame apertures, and the first gripper fluid against the first elastic member deforms the first elastic member and forms a plurality of first protrusions that engage the object, wherein each first protrusion extends through the gripper frame.

14. The gripper assembly of claim 12 wherein the first elastic member forms an elastic gripper chamber that encloses the first gripper fluid, and the first deformer assembly includes an actuator that selectively deforms the gripper chamber to selectively create the plurality of first protrusions.

15. The gripper assembly of claim 12 wherein the first gripper fluid is a viscous gel.

16. A robotic arm assembly that includes the gripper assembly of claim 12 and a robotic arm that moves and positions the gripper assembly.

17. A method for selectively gripping an object, the method comprising:
providing a first gripper subassembly that includes a first elastic member; and
urging a first gripper fluid against the first elastic member to deform the first elastic member and form a plurality of spaced apart first protrusions that engage the object.

18. The method of claim 17 wherein providing a first gripper subassembly includes the first elastic member forming an elastic gripper chamber that encloses the first gripper fluid, and wherein urging a first gripper fluid includes using an actuator to deform the elastic gripper chamber.

19. The method of claim 17 wherein providing a first gripper subassembly includes providing a gripper frame that engages the first elastic member, the gripper frame including a plurality of spaced apart frame apertures, and wherein each first protrusion extends through the gripper frame.

20. The method of claim 17 further comprising providing a second gripper subassembly that includes a second elastic member; and urging a second gripper fluid against the second elastic member to deform the second elastic member and form a plurality of spaced apart second protrusions that engage the object substantially opposite from the first protrusions.

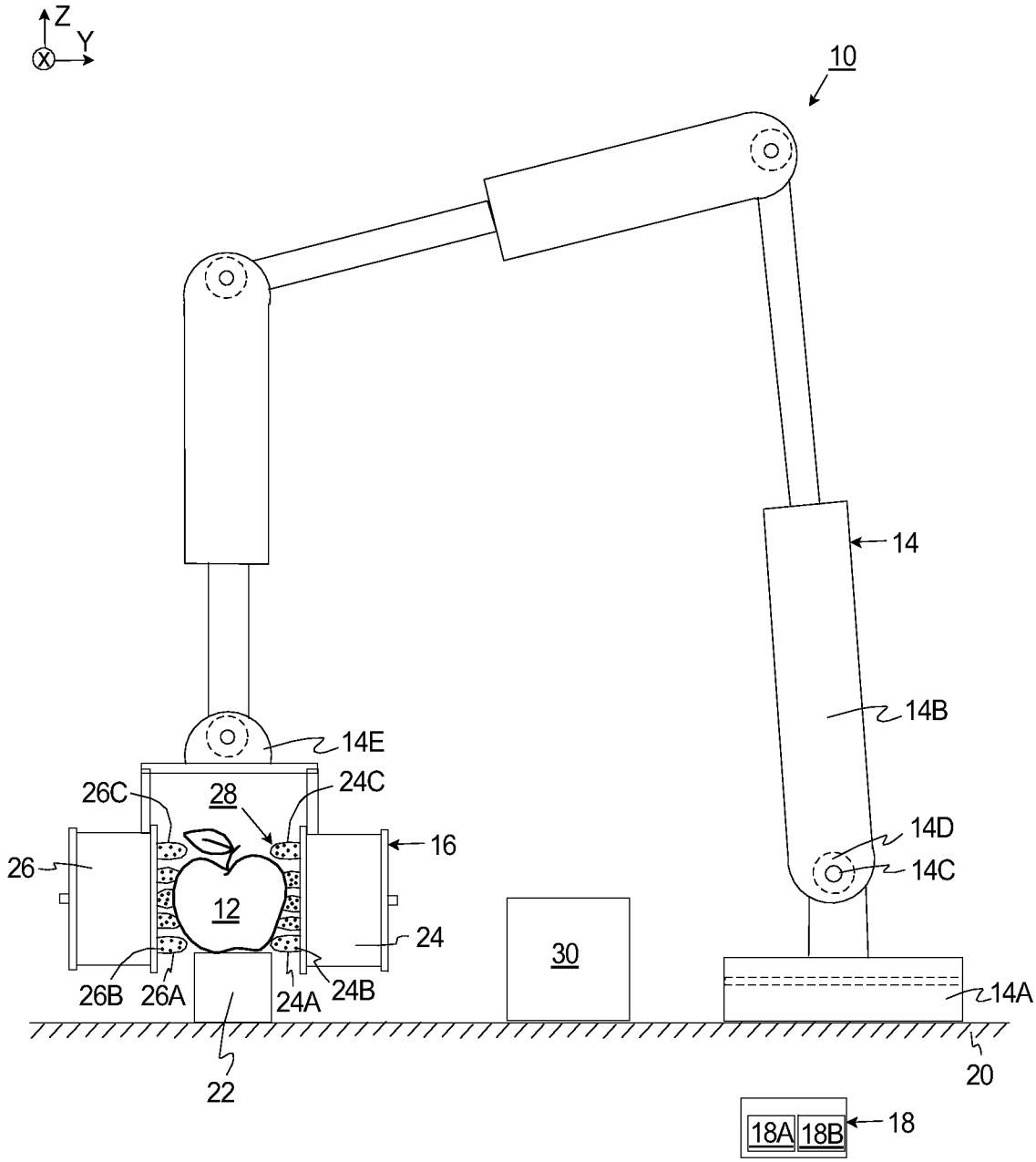

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Fig. 1

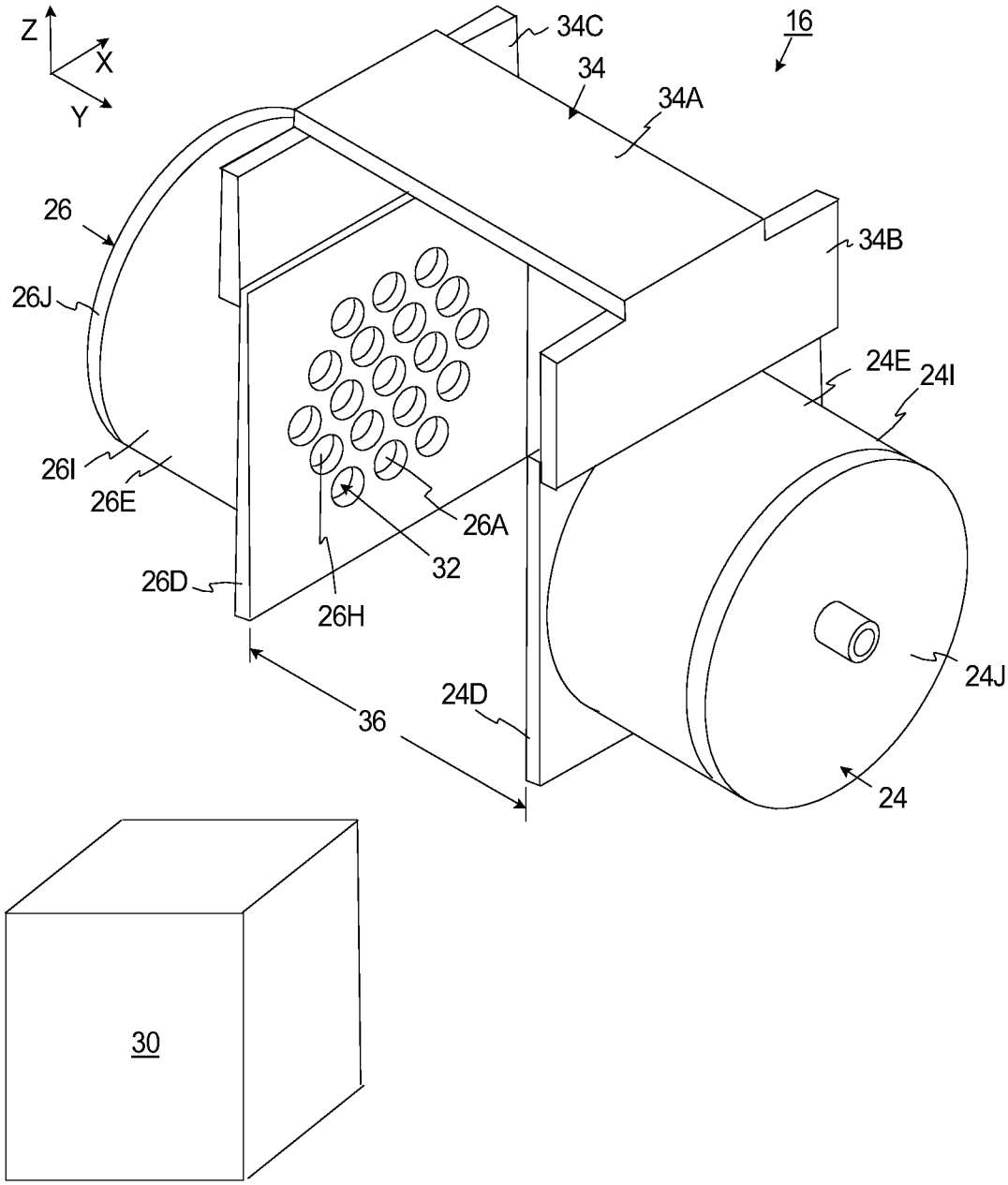

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Fig. 2A

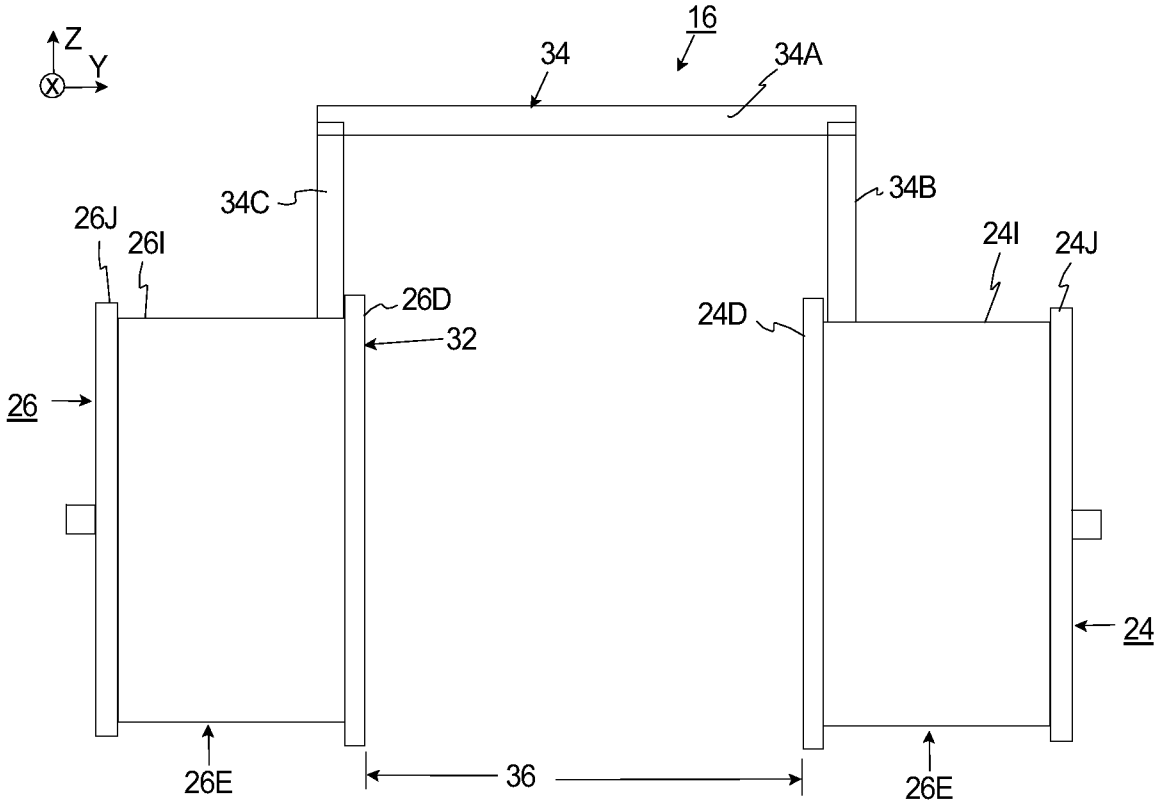

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Fig. 2B

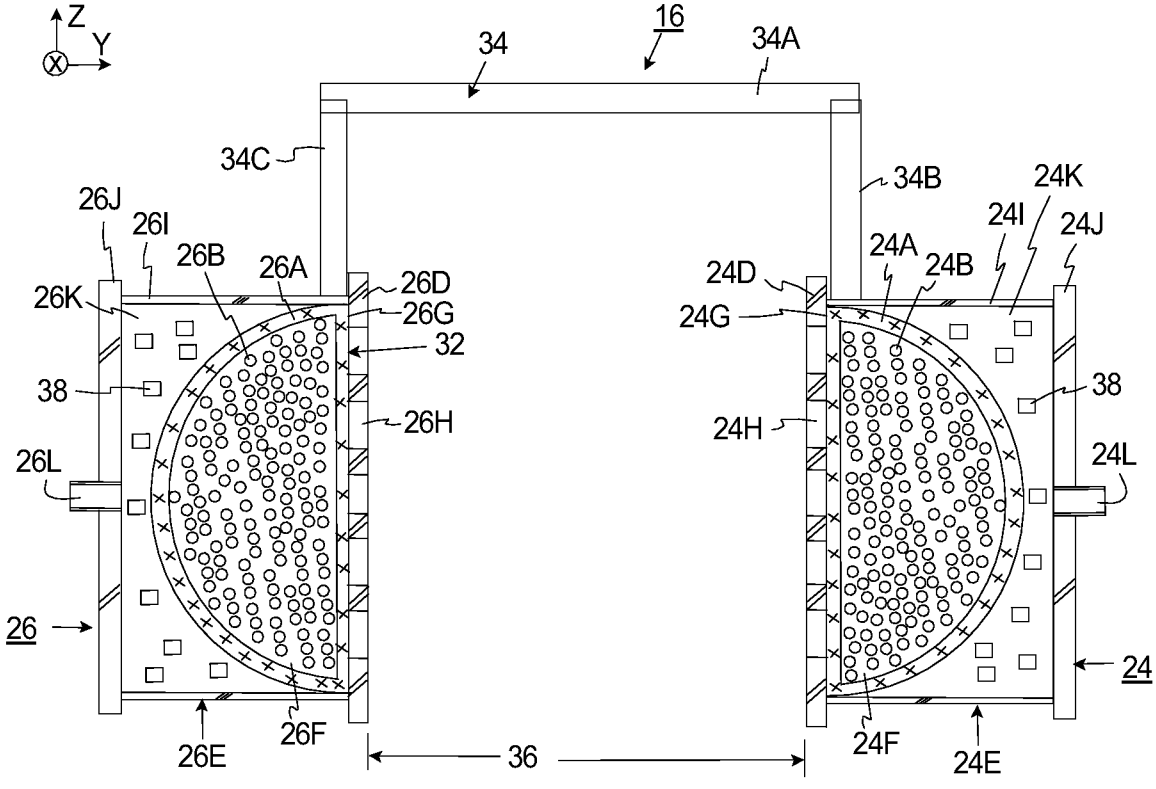

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24D
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Fig. 2C

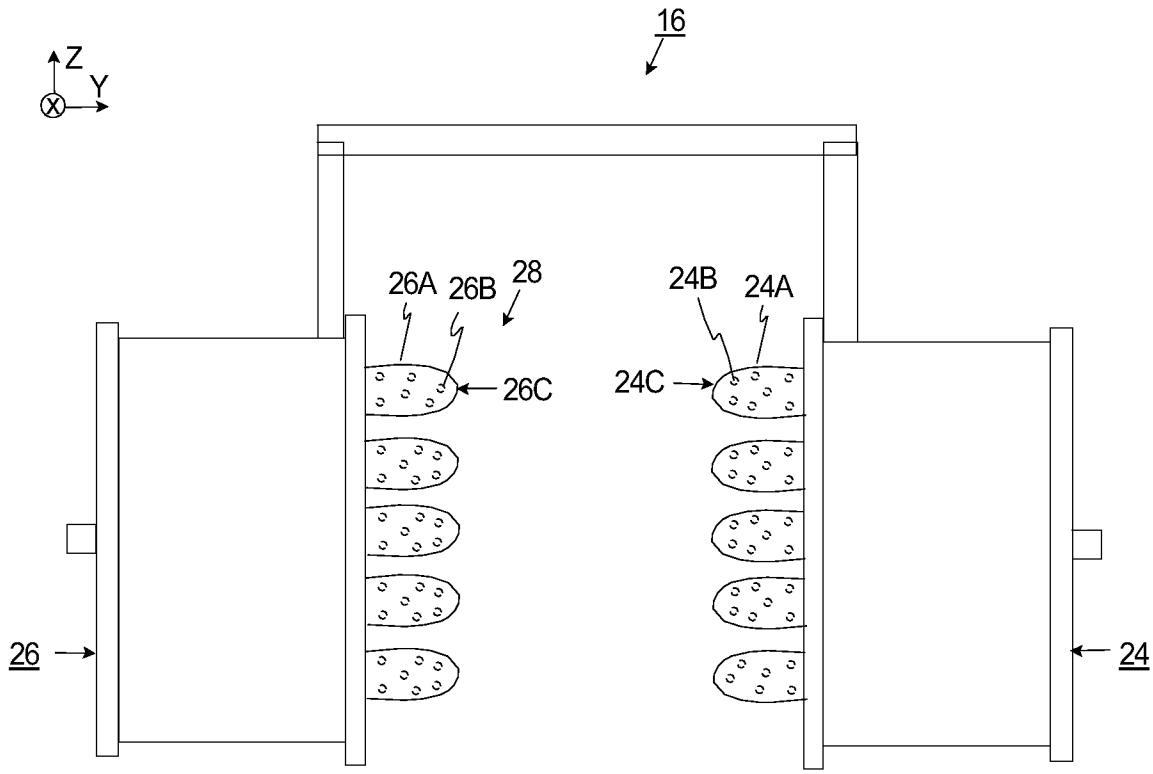

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Fig. 2D

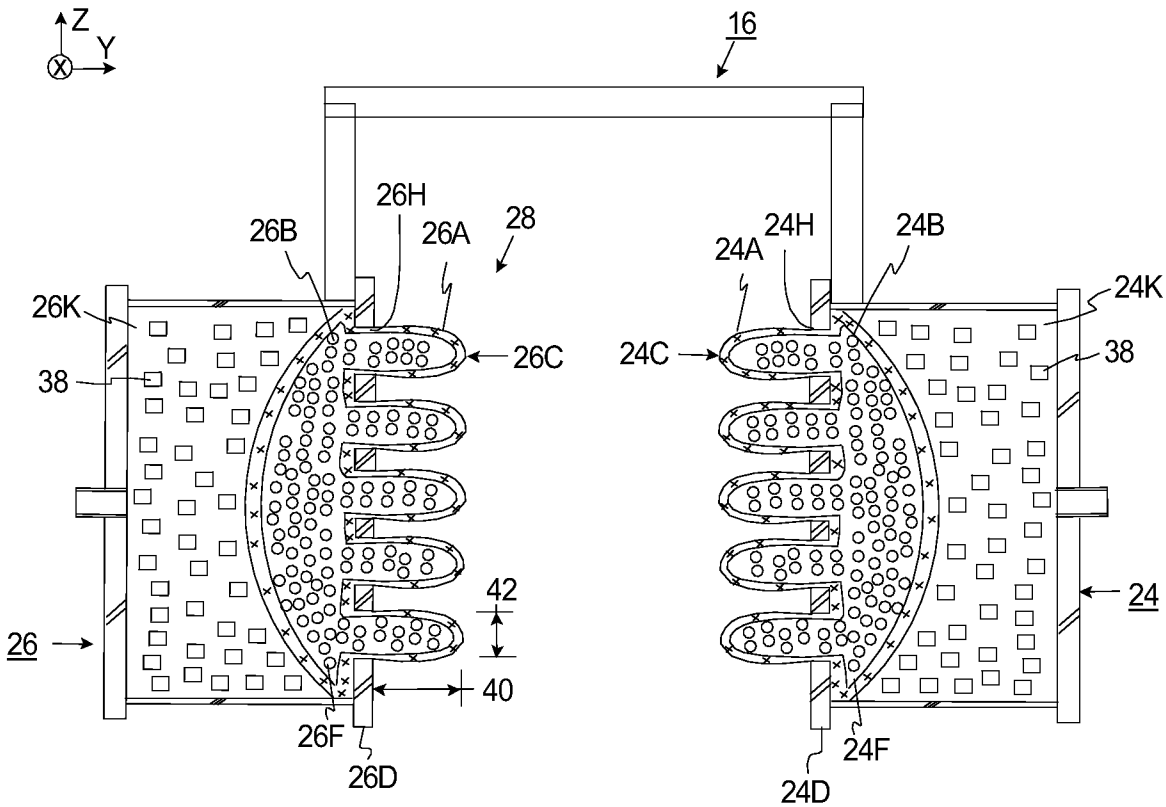

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Fig. 2E

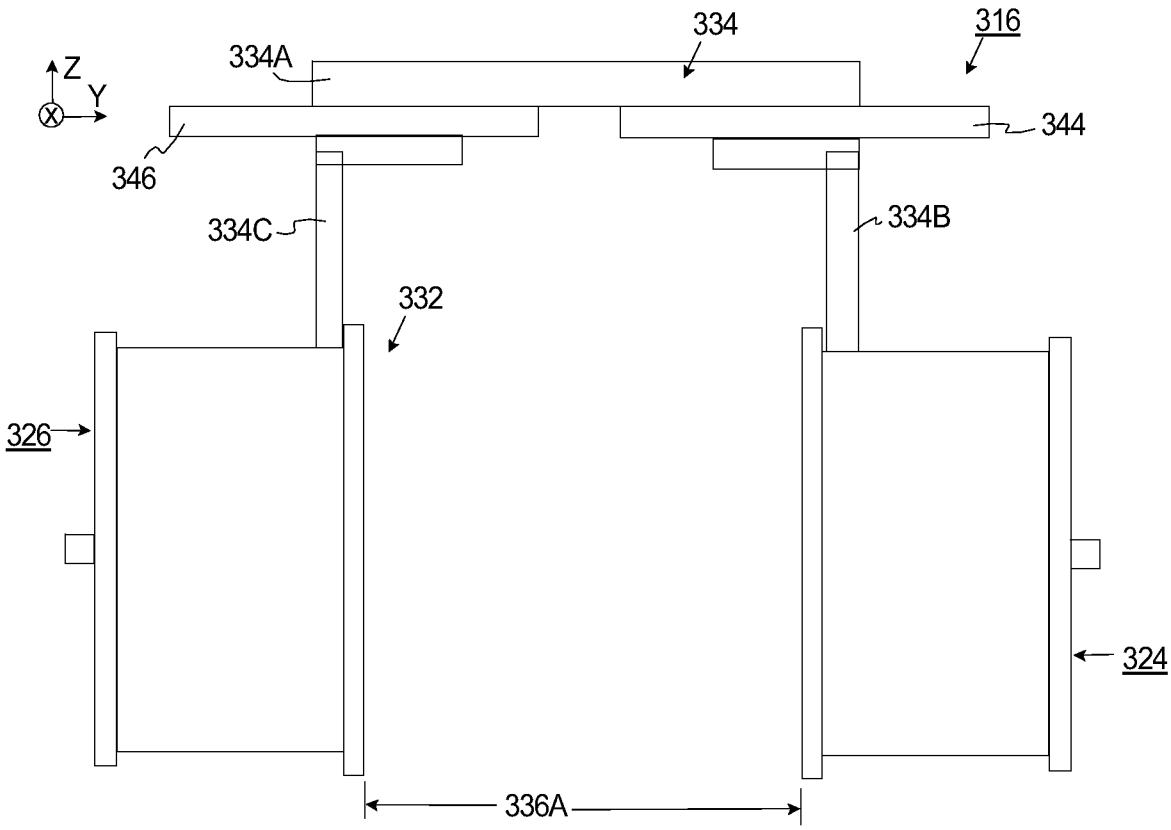

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Fig. 3A

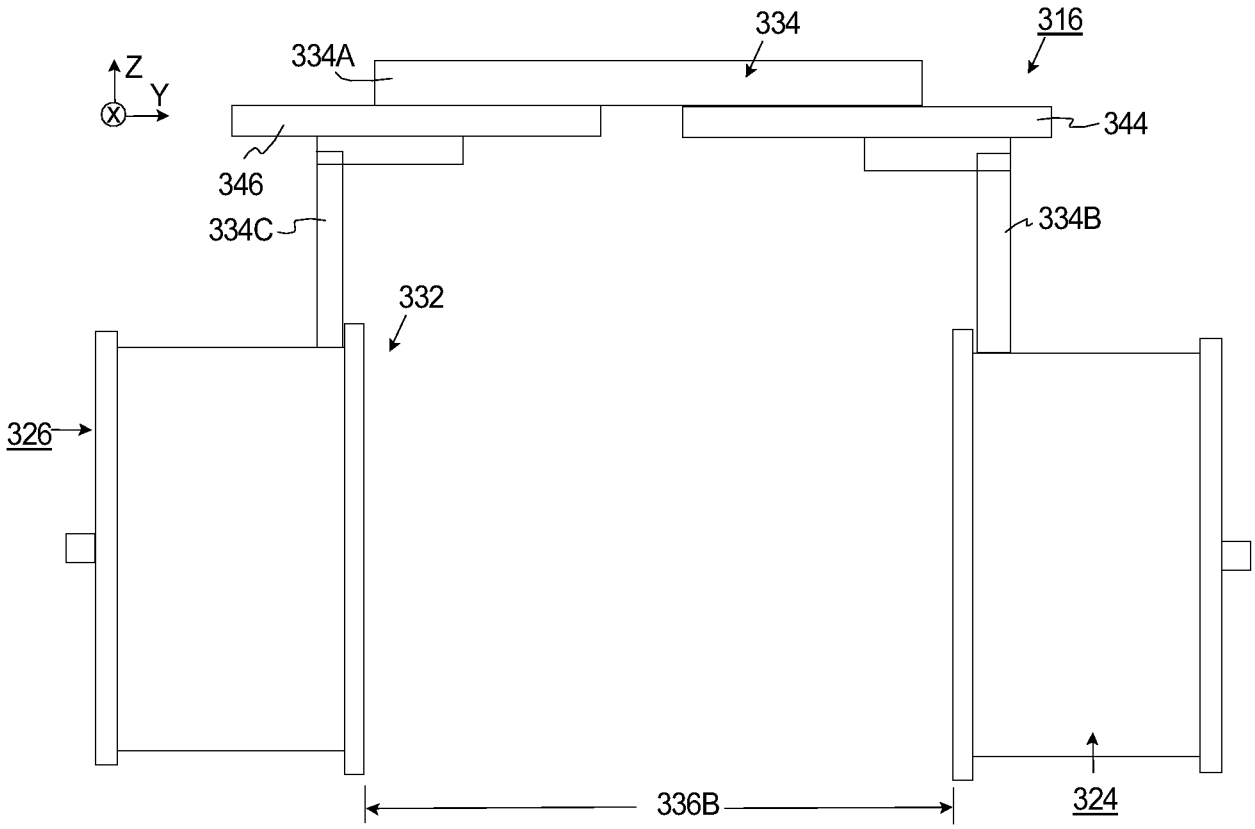

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Fig. 3B

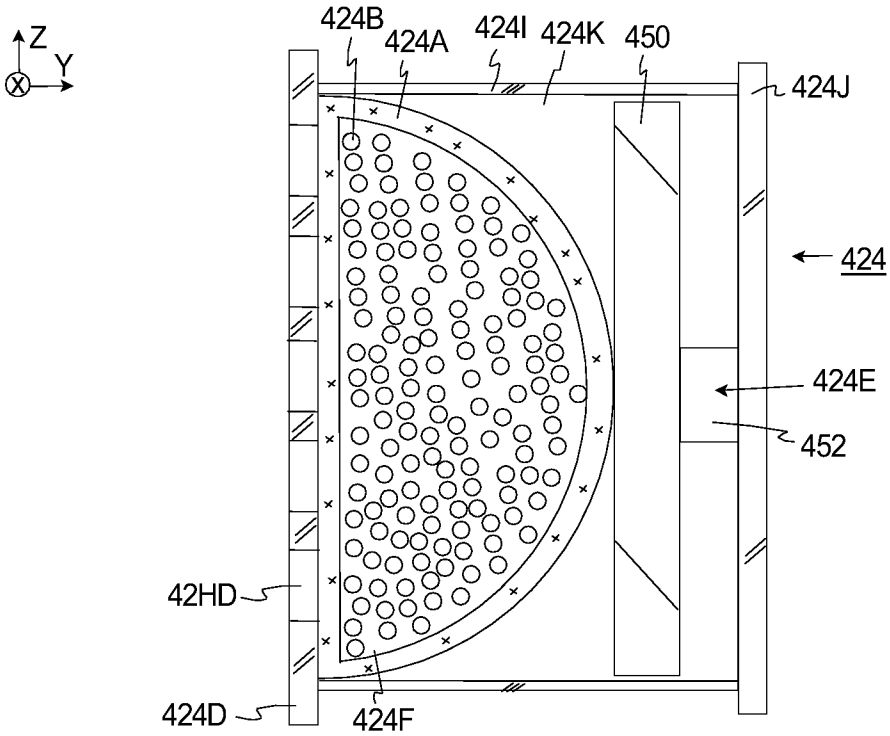

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Fig. 4A

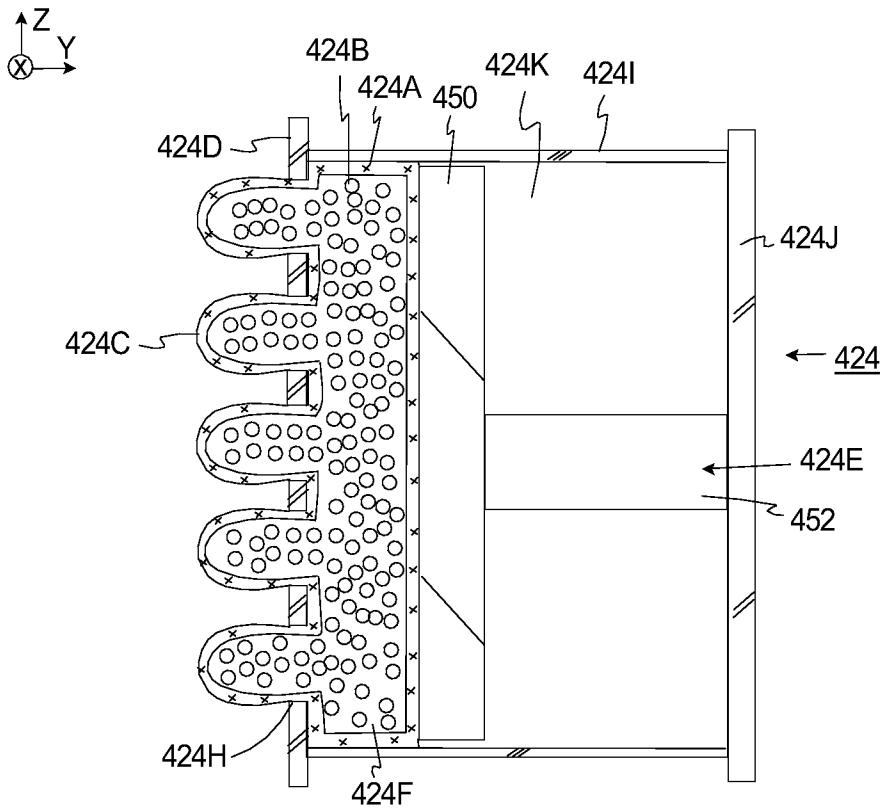

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Fig. 4B

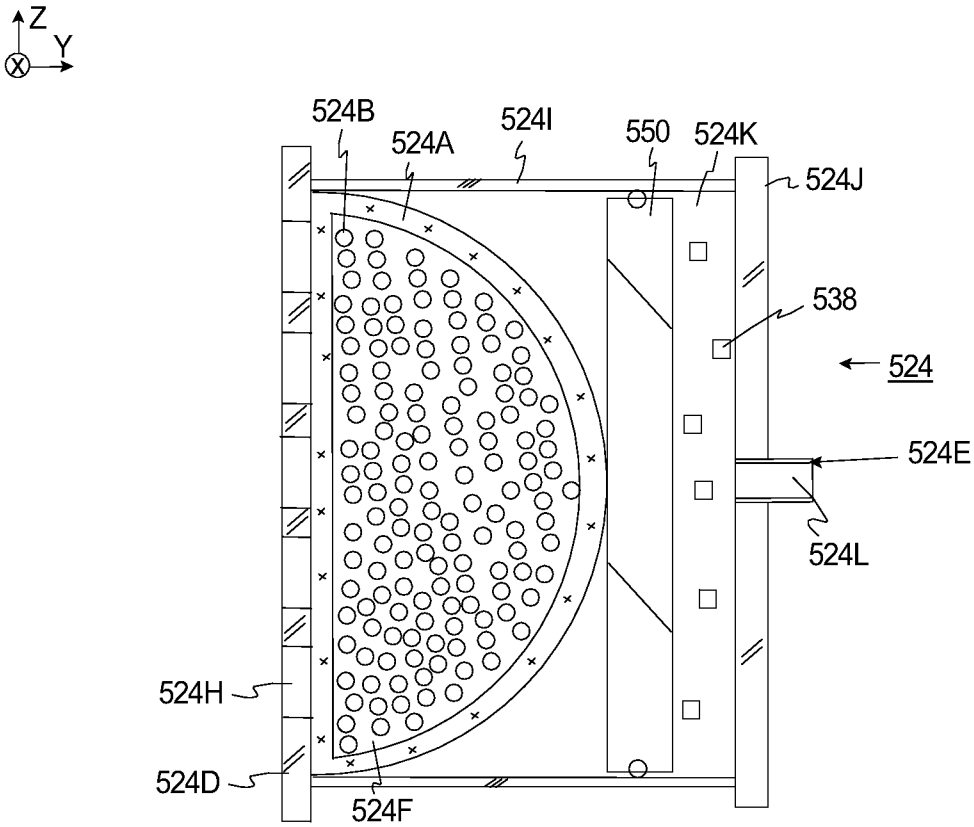

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Fig. 5A

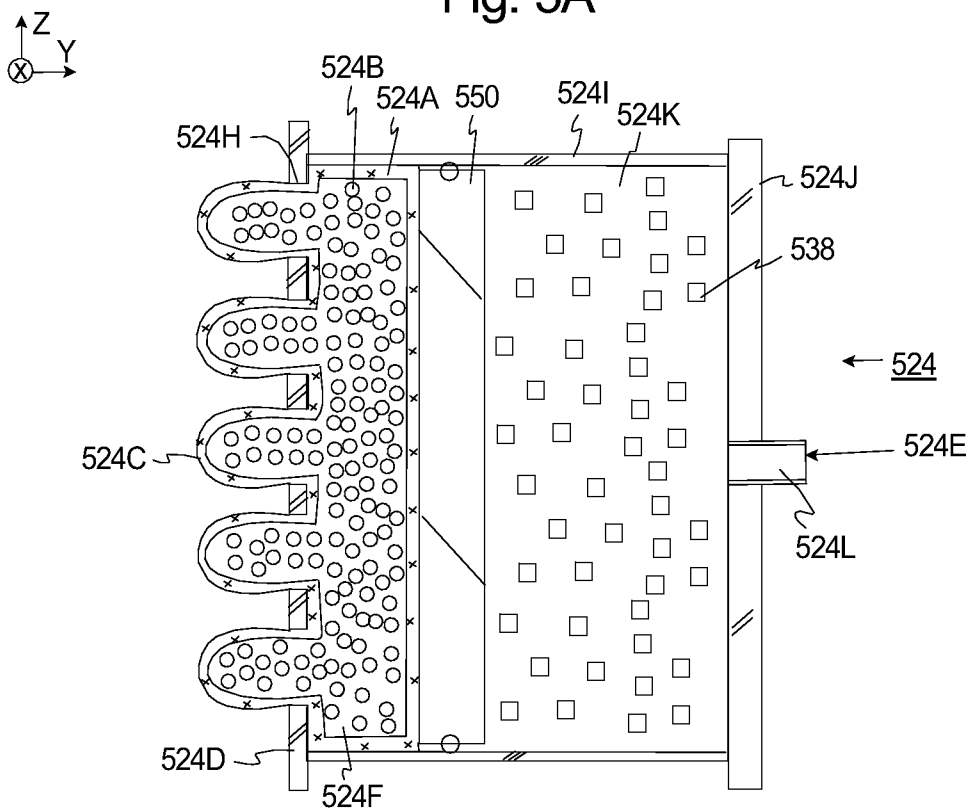

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550
524I
524K
524H
524J
538
524
524E
524C
524L
524D
524F

Fig. 5B

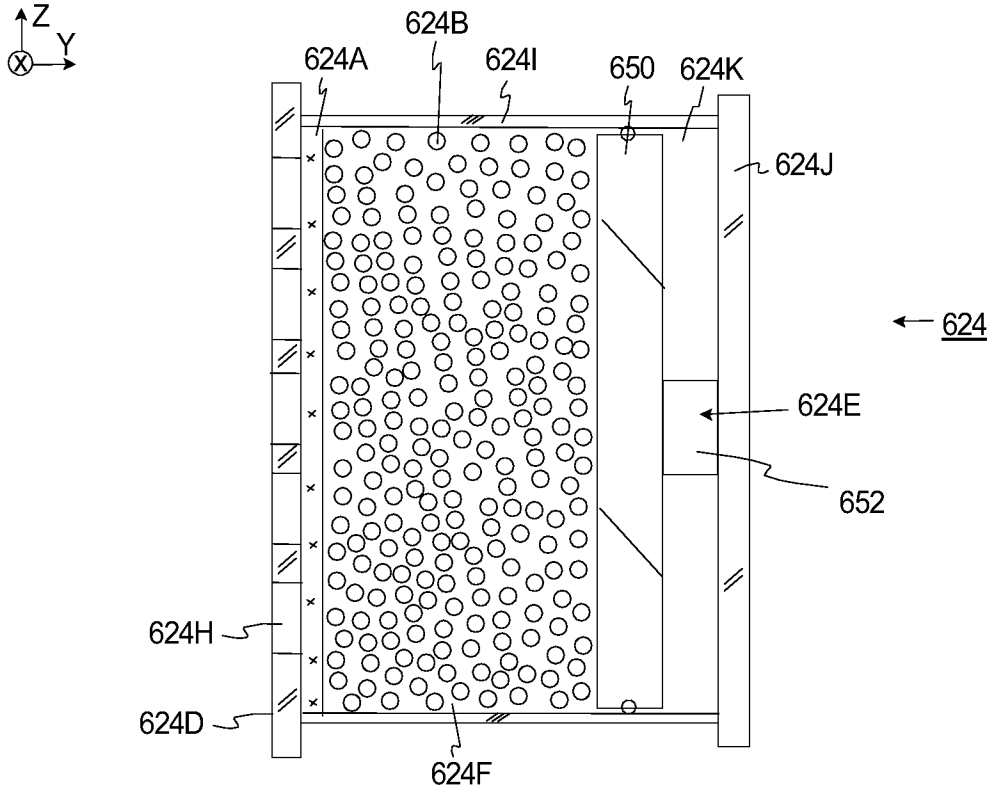

Z
Y
624B
624A
624I
650
624K
624J
624
624E
652
624H
624D
624F

Fig. 6A

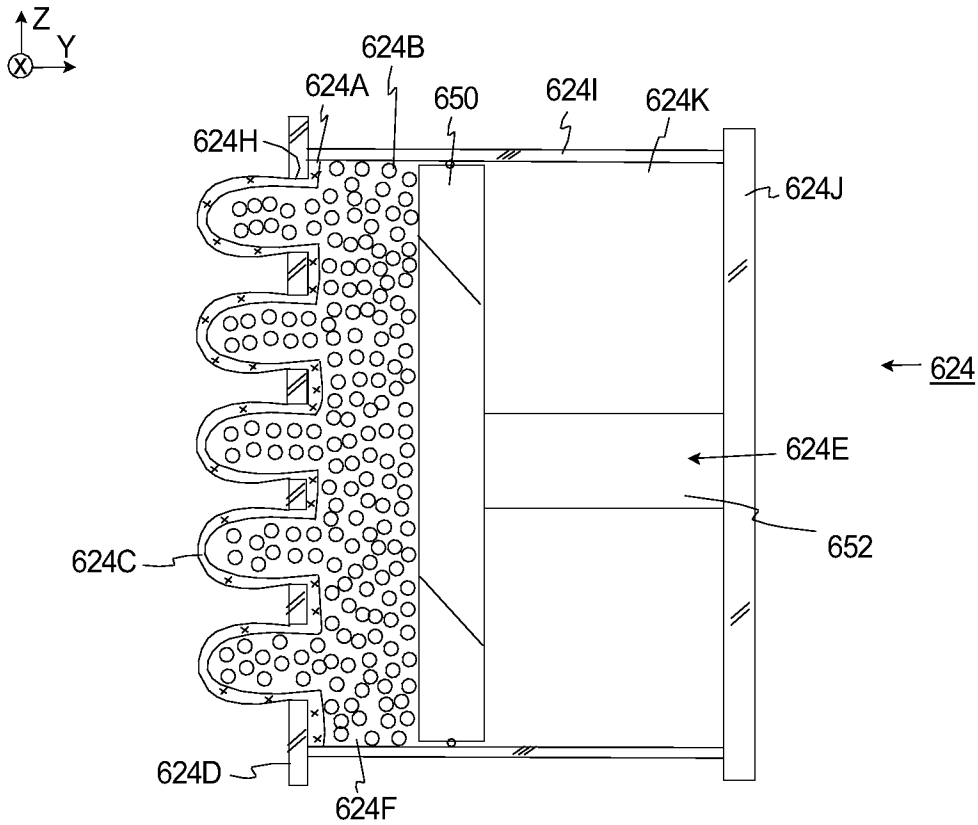

Z
Y
624B
624A
650
624I
624K
624H
624J
624
624E
652
624C
624D
624F

Fig. 6B

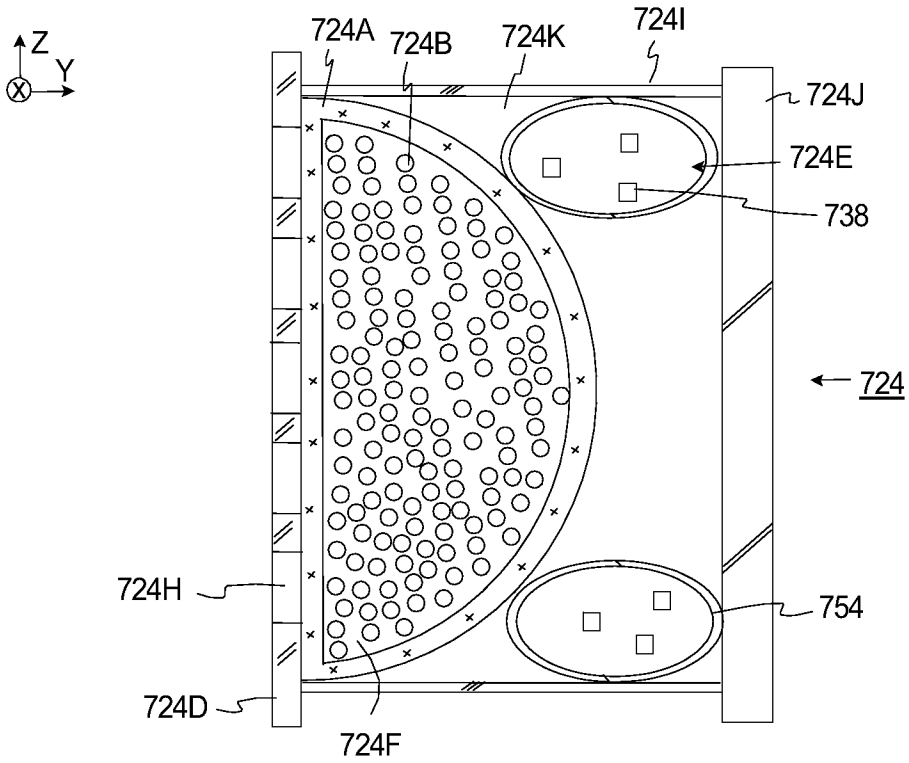

Z
Y
724A
724B
724K
724I
724J
724E
738
724
724H
754
724D
724F

Fig. 7A

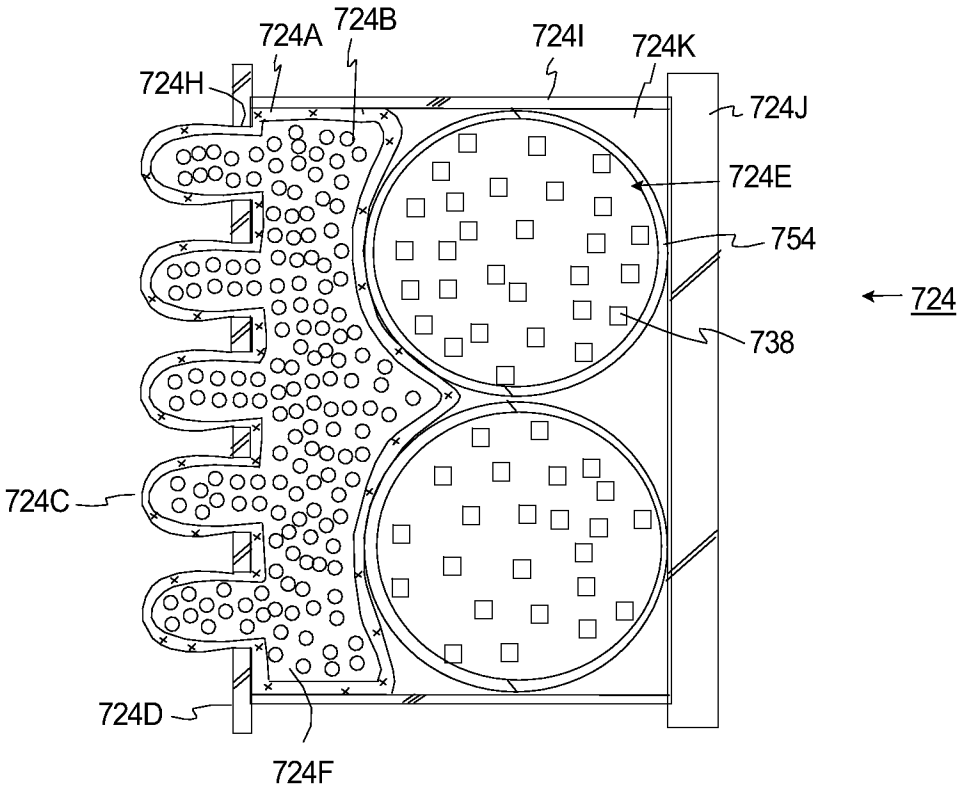

724A
724B
724I
724K
724H
724J
724E
754
724
738
724C
724D
724F

Fig. 7B

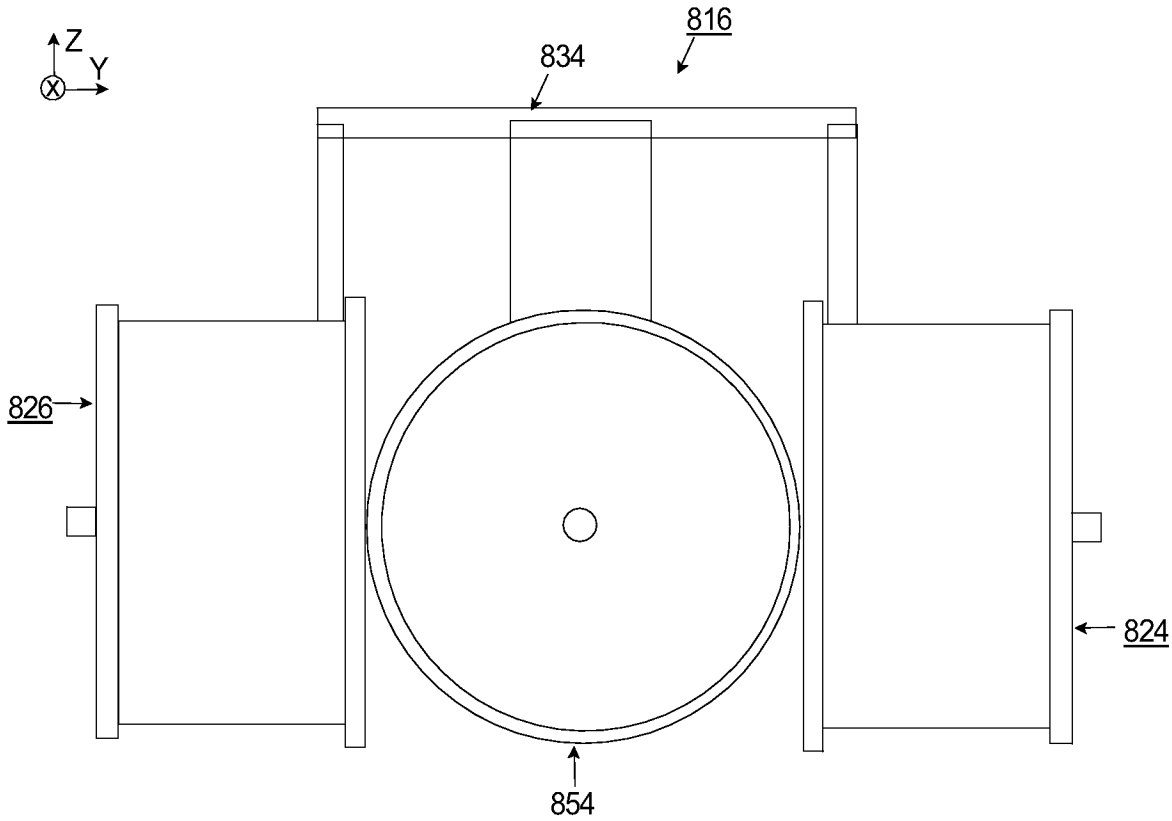


Fig. 8

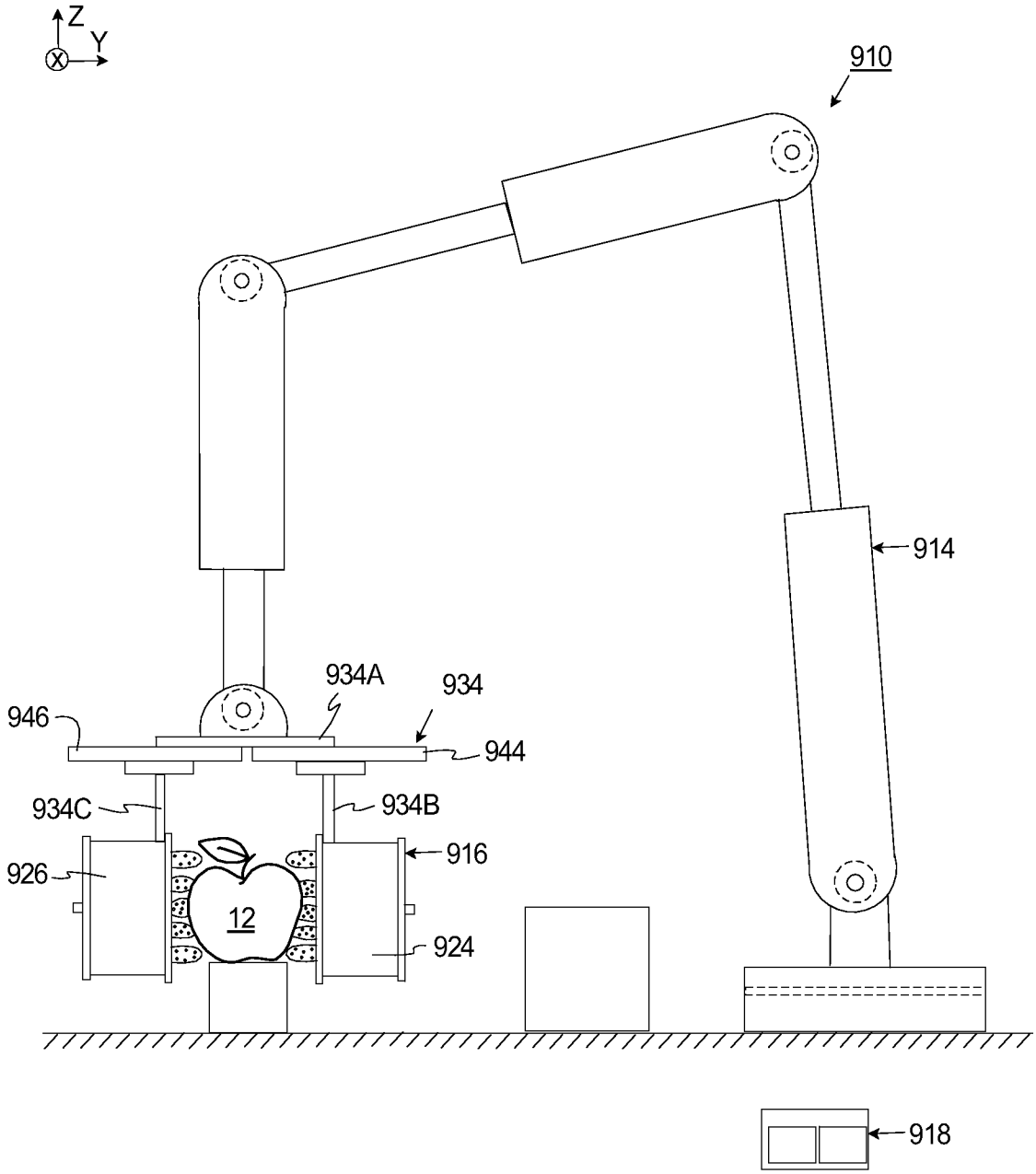


Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/000099

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25J15/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B25J

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2018/257241 A1 (CLARETTI ENNIO [US] ET AL) 13 September 2018 (2018-09-13)	1-4, 10-13, 16,17, 19,20
A	abstract; figures 3a-d paragraph [0023] paragraph [0024]	5-9,14, 15,18

X	JP S59 30694 A (MEIDENSHA ELECTRIC MFG CO LTD) 18 February 1984 (1984-02-18)	1,4-7, 14,18
A	figure 6	2,3, 8-13, 15-17, 19,20

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 June 2020	07/07/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Wanders, Christoffer

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/000099

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019/039838 A1 (CURHAN JEFFREY [US] ET AL) 7 February 2019 (2019-02-07)	1,8,9,15
A	paragraph [0053]; figures 10R, 10S	2-7, 10-14, 16-20

X	JP 5 762758 B2 (YAMAMOTO MOTOJI; SUNBIT KK) 12 August 2015 (2015-08-12)	1
A	abstract; figures 1-5	5-7,14, 18

X	NL 2 005 966 C2 (ROBOXIS B V [NL]) 10 July 2012 (2012-07-10)	1
A	abstract; figure 6	2-20

X	US 3 347 587 A (DAHLE FROST JAMES) 17 October 1967 (1967-10-17)	1
A	abstract; figures 4-7	2-20

X	US 5 403 056 A (WALLACE GARY L [US]) 4 April 1995 (1995-04-04)	1
A	figures 3,6	2-20

X	US 5 364 146 A (BRANDORFF ALEXANDER [US] ET AL) 15 November 1994 (1994-11-15)	1
A	figures 2-4	2-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2020/000099

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2018257241 A1	13-09-2018	US 2018257241 A1	13-09-2018
		WO 2018165106 A1	13-09-2018
JP S5930694 A	18-02-1984	NONE	
US 2019039838 A1	07-02-2019	EP 3661704 A1	10-06-2020
		US 2019039838 A1	07-02-2019
		WO 2019028242 A1	07-02-2019
JP 5762758 B2	12-08-2015	JP 5762758 B2	12-08-2015
		JP 2012148380 A	09-08-2012
NL 2005966 C2	10-07-2012	NONE	
US 3347587 A	17-10-1967	NONE	
US 5403056 A	04-04-1995	NONE	
US 5364146 A	15-11-1994	NONE	