

(NASA-Case-GSC-13370-1) SPLIT RAIL  
GRIPPER ASSEMBLY AND TOOL DRIVER  
THEREFOR Patent Application (NASA)  
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NASA Case No. GSC-13370-1

Print Figure 1

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## AWARDS DIGEST

GSC13,370-1

As shown in the Figures and more particularly in Figures 1, 5 and 6, a split rail gripper in accordance with this invention is comprised of a pair of rails 32, 34, separated by triangularly arranged ball bearings 38, 40, 42, 44, which are driven in mutually opposite directions by a rack and pinion gear mechanism, shown in Figures 7, 8 and 9. There each rail includes a set of rack gear teeth 106, 120, which engage respective pinion gears 110, 116, and where the top rail 32 engaging the gear 110 is driven by a drive unit including a harmonic drive 60 and stepper motor 62 coupled to an acme screw 58. The other pinion gear 116 is driven by the top pinion gear 110 and engages the set of rack gear teeth 120 included in the bottom rail 34. As the top rail 32 is moved in or out by the drive unit, the upper pinion gear 110 is rotated, causing the other pinion gear 116, in turn, to rotate in the opposite direction. This causes the bottom rail 34 to move in an opposite linear direction relative to the top rail 32. An outwardly extending finger assembly 46, 48 is attached to respective ends of the rails, with each finger comprising an arrangement of vertically and horizontally mounted roller members 68-74, 80 and 84-90, 92 which operate to automatically center and engage an H plate type interface 50 as shown in Figure 3 secured to the object 52 being grasped (Figure 4). The gripper assembly also includes a base plate 26 to which is attached a motor mount 64 including a load cell as shown in Figure 10 for measuring the gripping force exerted by the fingers 46, 48. A telescoping section type retractable rotary tool driver 54 and tool 56 is also centrally mounted on the base plate 26.

Novelty is believed to reside primarily in the concept of the two rails being separated by four crossed-roller bearings which form two stable triangles and gripper fingers each of which include two pairs of horizontal rollers and an intermediate vertical roller whose axes lie in a common plane.

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Employer: National Aeronautics and Space Administration

SPLIT RAIL GRIPPER ASSEMBLY AND TOOL DRIVER THEREFOROrigin of the Invention

This invention was made by an employee of the U.S. Government and accordingly may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

Field of the Invention

The present invention relates generally to robotics and more particularly to apparatus for robotically gripping objects, for example, in zero gravity environments and to operate a retractable rotary tool.

5 Background of the Invention

Where there is a need to position and remotely control machinery with a high degree of precision, robots are often used to perform these tasks. Robots in the past have been utilized to perform both simple and  
10 complex tasks in various environments, particularly where human activity is inaccessible, prohibited or relatively hazardous. More recently robotic type apparatus has been put to use in outer space. Typically where such robots are used, either tools or end-effectors are attached to  
15 movable robot arms so that objects can be grasped, lifted, manipulated and otherwise operated upon.

One known type of end-effector comprises a gripper comprised of two mutually opposing jaws that are movable with respect to one another in opposite directions by a  
20 rack and pinion gear mechanism. Such apparatus is shown, for example, in U.S. Patent 4,707,013 issued to John Vranish et al on November 17, 1987, and which is herein meant to be incorporated by reference. There the gripper includes a pair of rails having parallel thrown motion  
25 with a gripper finger sub-assembly attached to opposite ends of each rail. A pair of preloaded linear bearings engage the outward surfaces of each rail and two roller

bearings spaced on either side of a pinion, all mounted on a common pinion shaft, engage the inward sidewalls of each rail. The rails are typically driven by an electric motor.

5           Further, the gripper design as disclosed in U.S. Patent 4,707,013 incorporates separate racks that need to be first fabricated and then bolted to the rails, increasing the weight and bulk and making it relatively complicated to assemble. In order to achieve sufficient  
10 strength in the pinion shaft bearing, moreover, the back of the gripper housing protrudes significantly, further adding to the weight and bulk of the gripper. Also, when the fingers experience a sideload, the rails tend to move sideways relative to one another. Because the ends of  
15 the other sides of the rails are fixed, it has the effect of spreading the housing, eventually bending it open, causing preload on the bearings to be lost.

          Strain gauges are also mounted on the fingers to sense gripper pressure, with service loops connecting to  
20 the gripper base. The service loops being subject to many cycles of flexing, have a tendency to snag on other parts of the gripper. Moreover, finger mounted strain gauges are easily damaged, if the part being gripped is inadvertently gripped on the finger shanks. Furthermore,  
25 strain gauges require individual calibration for each set of fingers to obtain reliable readings since each mounting situation is relatively different and the fingers vary slightly from element to element. Also, finger mounted strain gauges are sensitive to loads other  
30 than the finger grip force such as sideloads.

          It should also be noted that rotary tools, particularly those mounted on robot end-effectors, are generally not retractable and fully protrude into the

work space and as a result, generally require an actuator to release them.

Summary

Accordingly, it is an object of the present  
5 invention to provide an improvement in robotic apparatus.

It is another object of the invention to provide an improvement in a robotic gripper which is operable in a zero gravity environment.

It is a further object of the invention to provide  
10 an improvement in split rail robotic gripper apparatus for operation in outer space.

And yet another object of the invention is to provide an improved split rail robotic gripper which is fitted with a retractable rotary tool for operating on a  
15 workpiece being gripped.

Briefly, the foregoing and other objects are achieved by a split rail gripper comprised of a pair of rails which are driven in mutually opposite directions by a rack and pinion gear mechanism, wherein each rail  
20 includes a set of rack gear teeth which engage respective pinion gears and where the top rail engaging one of the pinion gears is driven by a harmonic drive and motor unit coupled to an acme screw. The other pinion gear is driven by the top pinion gear and engages the set of rack  
25 gear teeth included in the bottom rail. As the top rail is moved in or out by the drive unit, the upper pinion gear is rotated, causing the other pinion gear, in turn, to rotate in the opposite direction. This causes the bottom rail to move in an opposite linear direction  
30 relative to the top rail. An outwardly extending finger assembly is attached to respective ends of the rails, with each finger comprising an arrangement of vertically and horizontally mounted roller members which operate to

automatically center and engage an H plate type interface secured to the object being grasped. The gripper assembly also includes a base plate attached to an interface plate of a robotic tool changer mechanism. A  
5 retractable rotary tool driver and tool is centrally mounted on the base plate.

Brief Description of the Drawings

Other features, advantages, and objectives of the invention will be more readily apparent when the  
10 following detailed description of the invention is considered in conjunction with the accompanying drawings, wherein:

Figure 1 is a perspective view generally illustrative of the split rail gripper in accordance with  
15 the preferred embodiment of the invention;

Figure 2 is a partial perspective view being illustrative of the roller members located at the upper end of the gripper fingers;

Figure 3 is a perspective view illustrative of an H-plate type interface member which is engageable with the  
20 rollers of the gripper fingers shown in Figure 1;

Figure 4 is a partial front plan view illustrating the gripper fingers engaging a workpiece and with the retractable tool holder and tool shown in Figure 1  
25 extended into the workpiece;

Figure 5 is an end plan view of the embodiment shown in Figure 1;

Figure 6 is a top plan view further illustrative of the embodiment shown in Figure 1;

30 Figure 7 is a sectional view taken along the lines 7-7 of Figure 6 and being illustrative of the bearing configuration between the top and bottom rails;

Figure 8 is a partial schematic view illustrative of the rack and pinion gear assembly included in the embodiment shown in Figure 1;

5        Figure 9 is a sectional view taken along the lines 9-9 of Figure 6 and being further illustrative of the rack and gear pinion gear assembly for moving the top and bottom rails;

10       Figure 10 is a partial cross-sectional view illustrative of the details of the strain gauge motor mount for measuring the force exerted by the gripper fingers shown in Figure 1; and

Figure 11 is a partial end planar view illustrative of the means for coupling the acme screw shown in Figure 1 to the top rail gripper finger.

15       Detailed Description of the Invention

Referring now to the drawings wherein like references numerals refer to like components throughout, reference is first made to Figure 1 where there is shown what is considered to be the preferred embodiment of the invention and wherein reference numeral 20 denotes a gripper and tool driving assembly which is adapted to be grasped by a robotic arm, not shown, via an interface plate 22 of a robotic tool changer mechanism, not shown. Such a tool changer mechanism, however, is disclosed in U.S. Serial No. 07/608,657 (GSC 13,239-1), entitled, "Robotic Tool Change Mechanism", which was filed on behalf of the present inventor on November 2, 1990, and which is also intended to be incorporated herein by reference. On the rear edge of the interface plate 22 there is an electrical connector 24 which is also adapted to be connected to the robotic arm to which the gripper assembly 20 is attached.

The gripper assembly is primarily comprised of a baseplate 26 which mounted on a tool motor drive assembly 28 secured to the interface plate 22 and including electrical drive motor 30 extending out to one side. The gripper itself is comprised of two elongated rails, namely a top rail 32 and a bottom rail 34, which are operable to extend partially out of a housing 36 and being mutually separated for crossed roller bearings, which is shown by reference numerals 38, 40, 42 and 44 as shown in Figures 5 and 7 and which will be discussed in further detail subsequently.

Attached to opposite ends of the top and bottom rails 32 and 34 are a pair of outwardly projecting finger members 46 and 48 which are adapted to move toward and away from each other to grip an H plate interface member 50 shown in Figure 3 and to which is attached a workpiece as shown in phantom view by reference numeral 52 of Figure 4 and which is to be operated on by a retractable tool mechanism 54 containing a rotatable tool 56. Movement of the gripper fingers 46 and 48 is controlled by an acme screw member 58 connected between the lower end of the finger member 46 attached to the upper rail 32 and a harmonic drive gear reduction mechanism 60 and electric motor 62 which are secured to a motor mount and base structure 64 affixed to the baseplate 26 by a housing 61. The motor mount 64 also includes a load cell 66 as shown in Figure 10 for measuring the gripping reaction forces on the finger elements 46 and 48.

Referring now to Figure 2, shown thereat are the details of the gripper elements located at the outer end of the fingers 46 and 48. As shown, the end of the finger 46 includes first and second pairs of rollers 68, 70 and 72, 74 which are respectively aligned on a pair of



parallel horizontal axes 76 and 78. A fifth roller 80 is located between the rollers 68, 70 and 72, 74 at mutually right angles thereto and is aligned along a vertical axis 82 which intersects the parallel axes 76 and 78. In a like manner, the opposite finger 48 includes the same arrangement which is shown in Figure 1; however, only rollers 84, 88 and 92 are shown consisting of an upper pair of horizontal rollers 84, 86, a lower pair of rollers 88 and 90, and an intermediate orthogonal vertical roller 92. The upper pair of rollers 84 and 86 are depicted in the top planar view of Figure 6.

The configuration of the roller members located at the ends of the two fingers 46 and 48 are operative to automatically position and grip the opposite ends of the H plate type interface member 50 shown in Figure 3. Referring now briefly to Figure 3, the interface plate 50 is comprised of beveled bifurcated ends of reduced width including pairs of end portions 94, 96 and 98, 100, between which are located two generally circular recesses 102 and 103.

In operation, as the two finger elements 46 and 48 are moved inwardly toward one another, the roller members at the ends thereof will contact the end portions 94, 96, and 98, 100, and automatically guide the plate 50 into position such that the recesses 102 and 103 straddle the two intermediate vertical rollers 80 and 92 as shown in Figure 4. This permits the retractable tool driver 54, which includes a plurality of telescoping sections 104, to be extended and position the tool 56, which may be, for example, a screw driver or a nut runner, at the workpiece 52 which is attached to the plate 50. As shown, the tool 56 comprises an allen wrench or key.

This now leads to consideration of the principal feature of the invention which is directed at the details of the way in which the two rails, the top rail 32 and the bottom rail 34, are supported and driven to control the position the two fingers 46 and 48.

As shown in Figures 5 through 9 and more particularly in Figure 7, the two rails 32 and 34 are located between the two bearings 38 and 42, while the other two bearings 40 and 44 are located one on top of the upper rail 32 and the other below the lower rail 34. Each rail 32 and 34 is accordingly supported by three intermediate bearings forming two stable triangles within the housing 36 which also acts as a housing to hold the various parts together.

Further as shown, the upper rail 32 includes a set of rack gear teeth 106 which engage the teeth 108 of an adjoining pinion gear 110 which is aligned along the axis 112, being mounted on a shaft 113 and supported by three sets of roller bearings 114, 116 and 118 and which might be referred to as a vertical axis parallel to the axis 82 shown in Figure 2 for the roller member 80. The pinion gear 108 is thus driven by translational motion of the upper rail 32 which is imparted by a linear motion of the acme screw 58 (Fig. 1) as will be shown.

The pinion gear 110 engages the teeth 114 of a second pinion gear 116 which is aligned along a second vertical axis 118 adjacent the axis 112 as shown in Figure 9. The gear teeth 114 extend downwardly to engage the gear teeth 120 of a rack formed on the side of the lower rail 34 as depicted in Figure 8. The elongated pinion gear 116, moreover, is supported by two pairs of bearings 122, 124 and 126, 128 (Fig. 9). When desirable, the single elongated pinion gear 116 can be implemented

by two smaller pinion gears mounted on the shaft 130 with one of the gears engaging the pinion 110, while the other engages the rack teeth 120 of the lower rail 34.

As noted above, the movement of the fingers 46 and 48 as controlled by operation of the two rails 32 and 34 in mutually opposite directions is provided by the acme screw 58. The acme screw 58 as shown in Figure 6, for example, is operated by a motor driven harmonic drive gear reduction mechanism 60 which rotates a nut 130, shown schematically in Figure 10. A harmonic drive is a well known device and typically consists of a wave generator member coupled to a shaft, a flexible cup-type spline and a circular spline which is attached to a motion coupling element. In the instant invention, the harmonic drive is preferably comprised of a pancake type harmonic drive and includes a dynamic circular spline, not shown, which is used to transfer its rotary output to the nut 130. The pancake type harmonic drive 60 is furthermore hollow so that the acme screw 58 can pass therethrough. Rotation of the nut 130 causes the acme screw to exert a pulling or pushing force on the rails by virtue of its connection to the upper rail 32. As shown in Figure 10, a motor 62 provides rotary input to the harmonic drive 60. The motor 62 typically comprises a hollow brushless DC motor so that the acme screw 58 can also pass axially therethrough.

The far end of the acme screw 58 terminates in a ball and socket joint including a flattened socket member 132 and a ball 133 which fits into an open ended rectangular end piece 134 secured to a rib section 135 projecting from the lower end of the finger 46 as shown in Figures 1 and 5. The ball 132 includes a through hole so as to accommodate a shoulder bolt 136 which fastens

the acme screw to the end piece 134. This type of coupling prevents the acme screw 58 from being turned and thus the rotating nut acts to linearly translate the acme screw 58 in and out of the harmonic drive 60 and motor 62. The shoulder bolt 136 is threaded such that it can be manually removed, when required, by inserting an allen screw, for example, at the head end 137 for disconnecting the acme screw from the rail 32 and thus releasing the fingers 46 and 48.

The manner in which the acme screw 58 is attached to the rail 32 via the end piece 134 insures sufficient energy is being provided to the screw 58 to break it free should it become frozen. Sufficient backlash is built into the attachment point between the acme screw 58 and the end piece 134 so that the socket end of the screw can rotate a few degrees on the ball 132 before encountering a stop. This allows the motor 62 on the input side of the gear reduction harmonic drive 60 to make one and one half free rotations before experiencing any load. In this fashion, sufficient kinetic energy can be built up to overcome large sticking forces between the screw 58 and the nut 130.

The gripping force exerted by the two fingers 46 and 48 is sensed by the load cell 66 as shown in Figure 10. The motor mount 64 includes top and bottom wall sections 138 and 140 accompanied by a hollowed mid section 142 which accommodates the load cell 66 and a pair of transverse relatively thin blade type connecting elements 144 and 146 between the wall sections 138 and 140. The friction between the acme screw 58 and the drive nut 130 is all in rotation. Accordingly, any pulling force is exerted on the blade elements 144 and 146 along the axis of the acme screw. The blade elements 144 and 146 are

stiff in all other axes and rotations. With the load cell coupled between the upper and lower wall sections 138 and 140 of the motor mount 64, it can measure the force that the drive motor 62 is exerting on the base and which is a direct function of the gripping force exerted by the fingers 46 and 48 through the harmonic drive gear reducer 60 and the acme screw.

With respect to the rotary tool mechanism 54 as shown in Figure 1, as noted above, it includes one or more telescoping sections 104 as well as the tool tip itself 56 which may be, for example, an allen key. The telescoping sections 104 are spring loaded and include keyway grooves, not shown, which permit the tool tip 56 to move axially while transmitting torque. When the tool tip 56 is inserted into an allen head, for example, on the workpiece 52 as shown in Figure 4, the spring loaded sections 104 provide compliance in the axial direction and press the tool 56 into the head. The final keyway where the tool tip is attached to the first section has a loose fit to allow the tool tip a small amount of lateral compliance, which is important for robotic applications. This compliance is not necessary, however, for operation of the tool 56 itself. When the rotary tool is no longer required, the telescoping sections 104 are axially compressed causing all the sections to collapse until the rear end of the tool tip shaft engages a catch, not shown, at the base of the tool. The catch keeps the tool 56 fully retracted until it is released. A release is achieved by activating the tool drive motor 30, whereupon the spring loaded telescoping sections 104 then extend to its full length.

Thus what has been shown is an improved workpiece gripper mechanism for robotically grasping objects in a zero gravity environment.

5        Having thus shown and described what is at present  
considered to be the preferred embodiment of the  
invention, it should be noted that the same has been made  
by way of illustration and not limitation. Accordingly,  
all modifications, alterations and changes coming within  
the spirit and scope of the invention are herein meant to  
10        be included.

ABSTRACT

SPLIT RAIL GRIPPER ASSEMBLY AND TOOL DRIVER THEREFOR

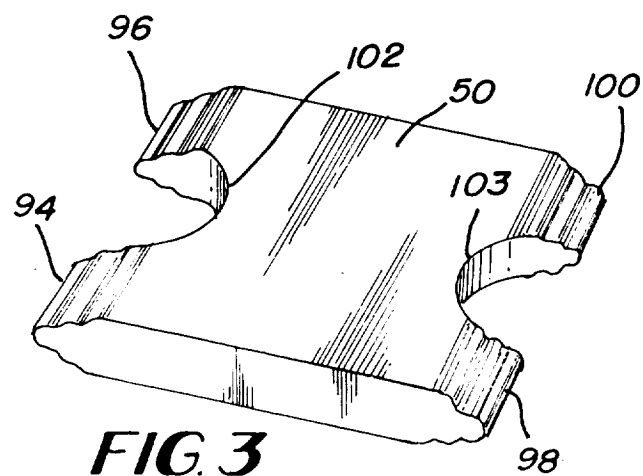
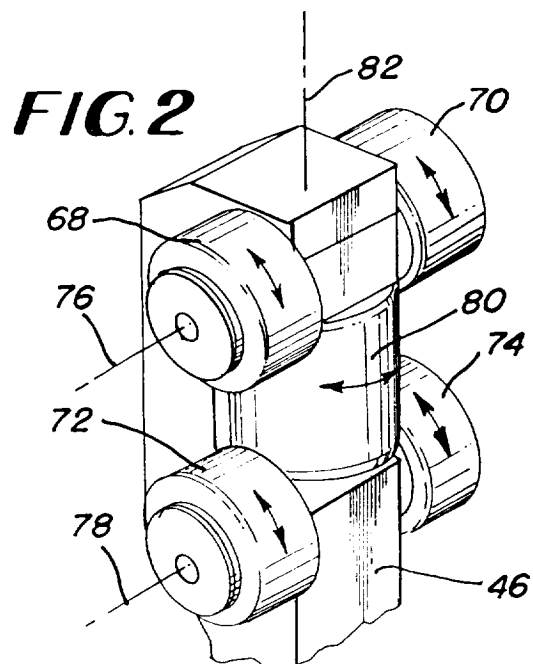
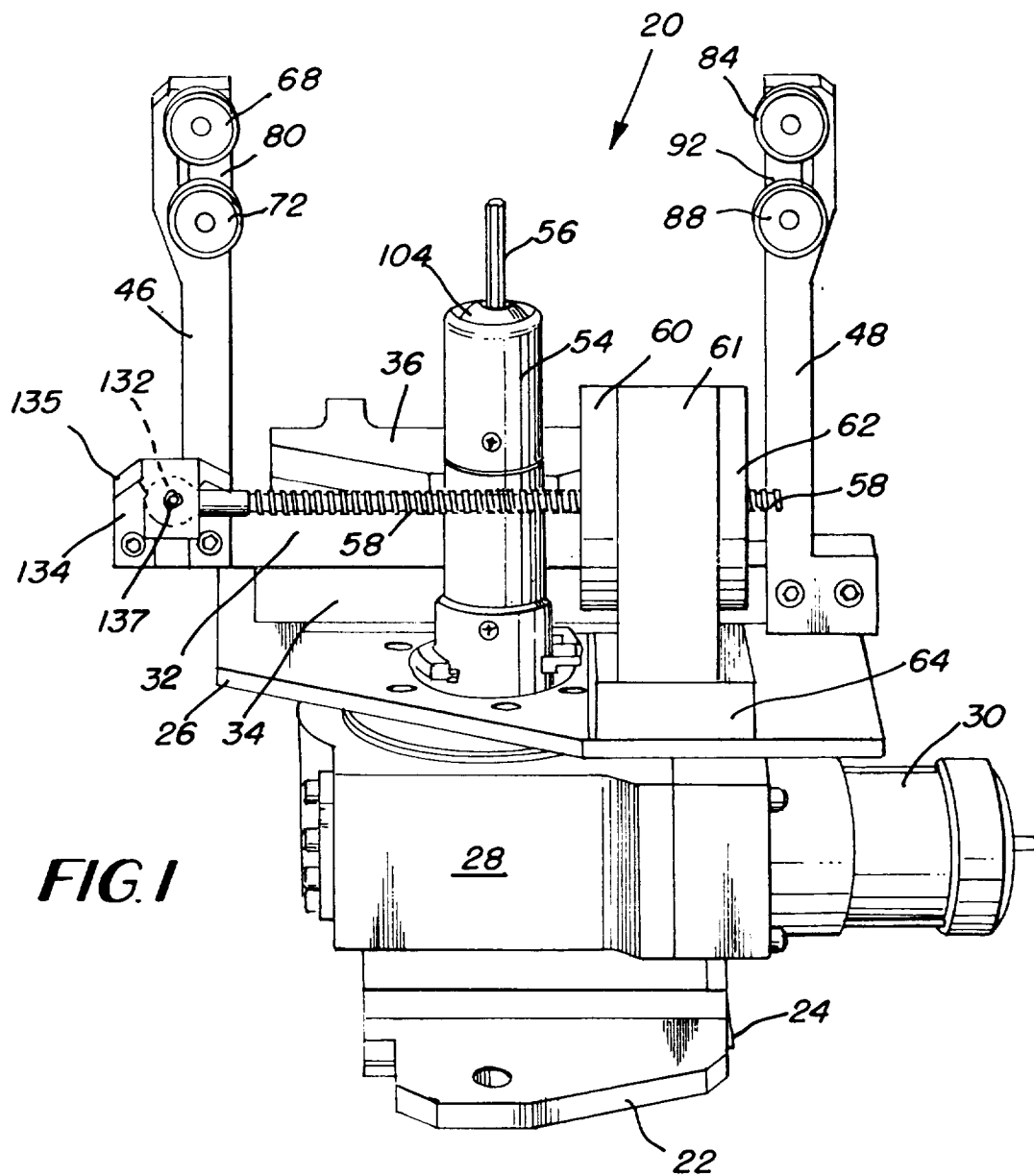
5 A split rail gripper for robotic apparatus and including a pair of rails which are driven in mutually opposite directions by a rack and pinion gear mechanism. Each rail includes a set of rack gear teeth which engage respective pinion gears and where the top rail engaging one of the pinion gears is driven by a harmonic gear reduction drive and motor unit coupled to an acme screw.

10 The other pinion gear is driven by the top pinion gear engaging a set of rack gear teeth included in the bottom rail. As the top rail is driven in or out, the upper pinion gear is rotated, causing the other pinion gear, in turn, to rotate in the opposite direction. This causes

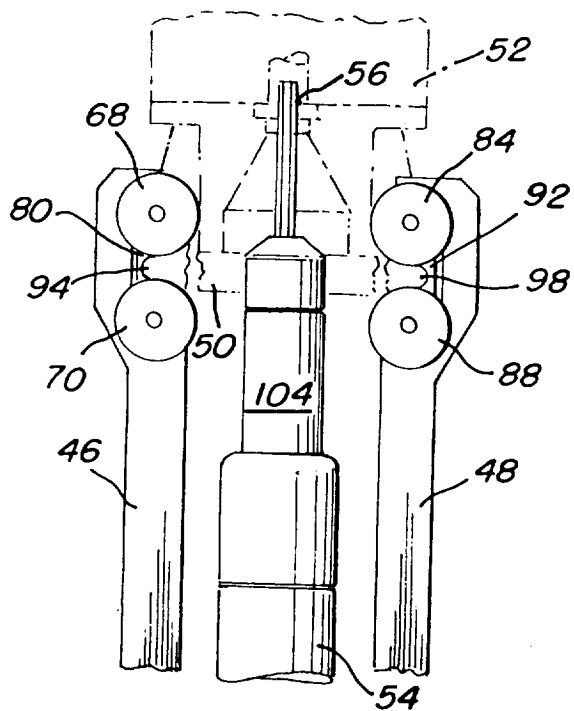
15 the bottom rail to move in an opposite linear direction relative to the top rail. An outwardly extending gripper finger assembly is attached to respective ends of the rails, with each gripper finger including an arrangement of vertically and horizontally mounted roller members

20 which operate to automatically center and engage an H-plate type interface secured to the object being grasped. The gripper assembly also includes a base plate attached to an interface plate of a robotic tool changer mechanism. A retractable rotary tool driver and tool is

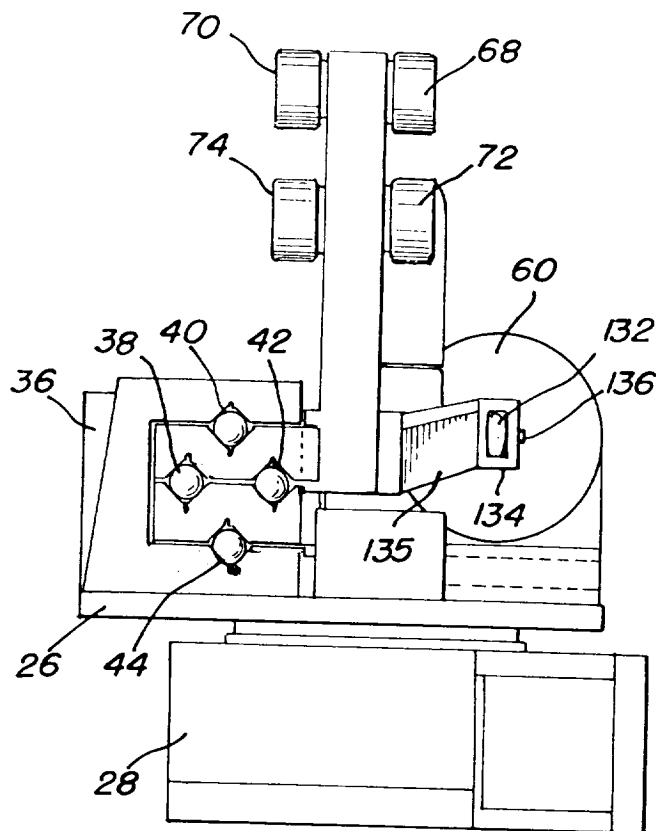
25 also centrally mounted on the base plate.



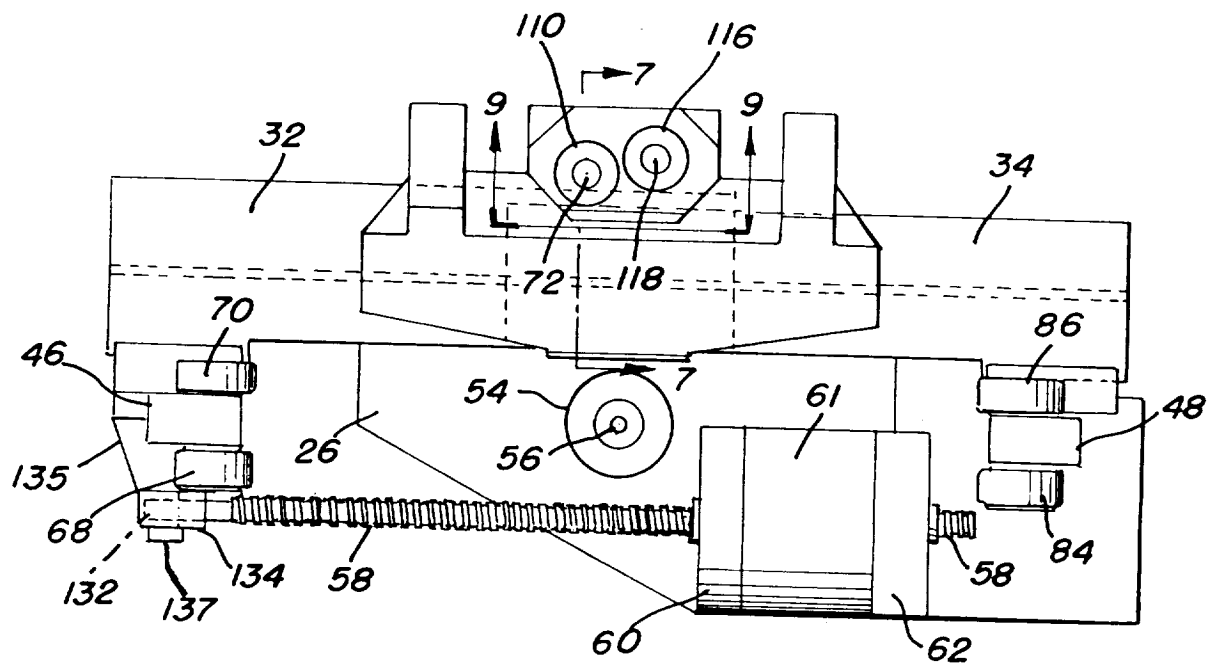




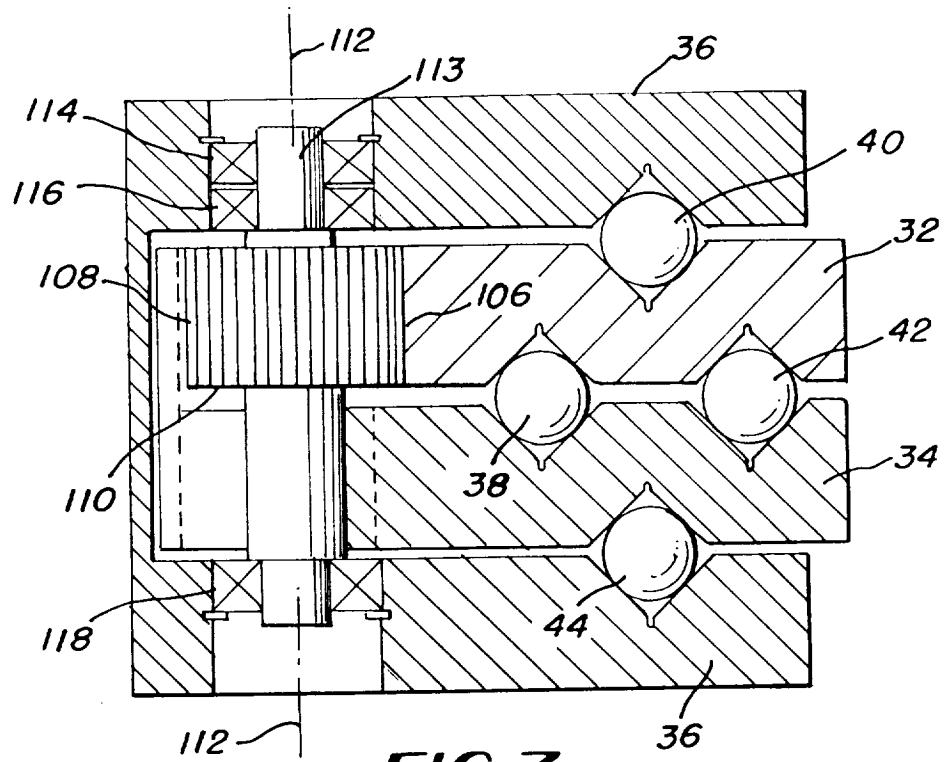
**FIG. 4**



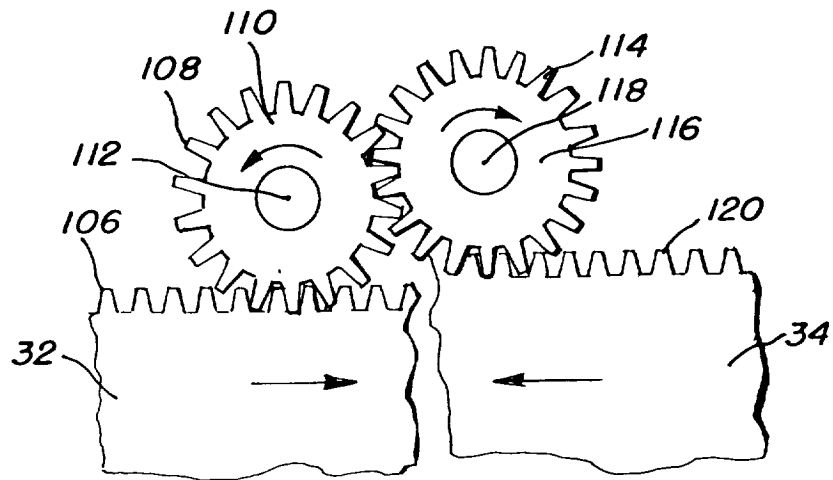
**FIG. 5**



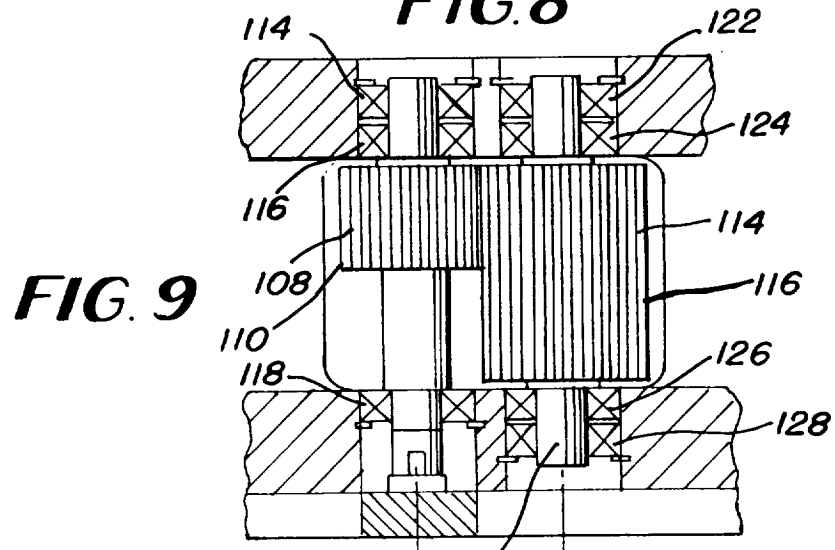
**FIG. 6**



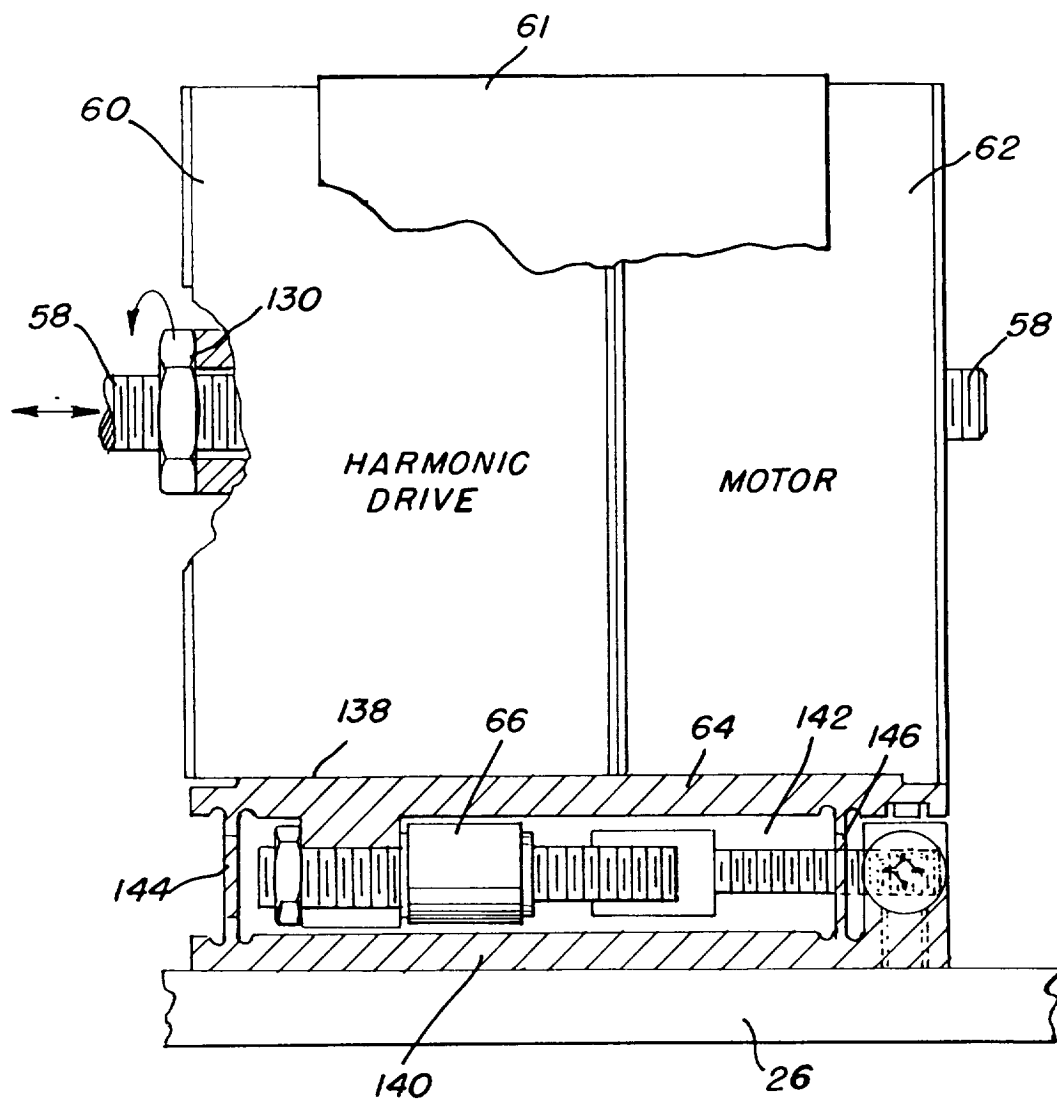
**FIG. 7**



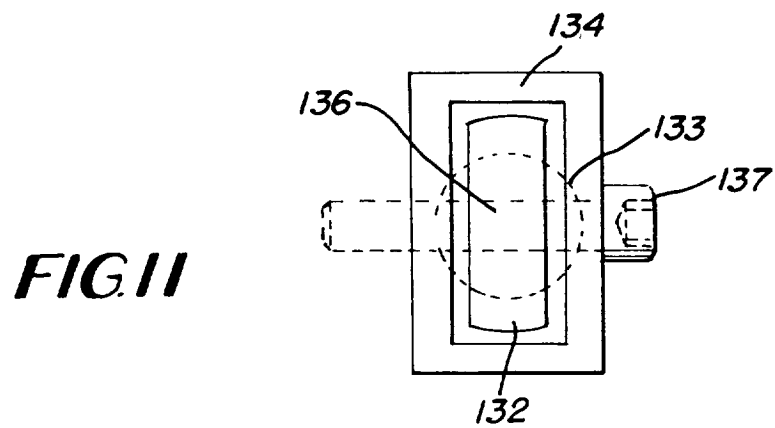
**FIG. 8**



**FIG. 9**



**FIG. 10**



**FIG. 11**