

Improvements in or relating to a workpiece manipulator.

THE PRESENT INVENTION relates to a workpiece manipulator, for example robotics and workpiece manipulators, and more specifically relates to a manipulator useful in applications wherein space limitations preclude use of conventional robotic manipulators, and especially useful for removing  
5 molded parts from a molding machine and placing the parts at a work station spaced from the mold.

Automatic manipulator apparatus have been developed for work operations such as welding, assembly, the removal and handling of parts, and  
10 other types of repetitive work cycles. Some known manipulators are programmable and allow the manipulator to be reused for different tasks requiring different sequences of movements through a variable work space.

One programmable, multi-axis, automatic manipulator assembly shown in U.S. Patent No. 4,275,986 comprises a manipulator having six axes  
15 of motion to provide flexibility in a sequence of movements for positioning a manipulator hand. Such a manipulator, as well as many other similar articulated-arm devices, has been found to be too large, expensive, and complex for some applications. For many basic pick-and-place operations,  
20 use of hydraulic power or precision encoder position control is simply overengineering.

At the opposite extreme of parts manipulation devices are apparatus such as disclosed in U.S. Patent No. 3,947,208. This device is used in press  
25 molding machines and the like, and includes an extracting arm mounted on a translating and rotating drive shaft moved by the opening of the mold. A cam mechanism causes the arm to swing into the space between mold halves to grip the parts, and thereafter to swing out of the machine and release the part. Although the device is comparatively simple and inexpensive, it is a  
30 dedicated device, not reprogrammable, and suffers especially from the drawback that it is unable to extract a part, reorient the part to another

plane, and discharge the part at a remote workstation. Such operations are frequently desirable for removing parts from a molding machine and placing the parts on a conveyor belt for further processing.

5        For injection molding factories, plant layout requirements sometimes dictate that molding machines be placed relatively close to one another, thereby limiting the amount of space available for a parts manipulator to remove the molded parts. There is often insufficient space for installation of a conventional multi-axis robotic manipulator. Even though smaller and  
10       lighter electrically driven manipulators having articulated joints are now commonly available, space limitations sometimes preclude use of these articulated-joint mechanisms because entry of the manipulator hand into the mold and retraction of the part forces the articulated arm to assume awkward positions, for example as the hand is guided between the tie bars of  
15       the molding machine and into the mold cavity between the mold halves. In some applications, it may be impossible to use an articulated-arm manipulator whose elbow might interfere with other machinery as the manipulator assumes its various positions in extracting and removing the parts.

20       In applications where space is at a premium, telescoping boom manipulators such as shown in U.S. Patent No. 3,916,701 have been proposed. This Patent discloses an industrial robot, for grasping, manipulating and moving parts, that includes a telescoping boom assembly mounted  
25       for movement about two orthogonal axes and a part gripper mounted on the forwardmost end of the telescoping boom assembly. The part gripper is rotatably movable about a third axis which is substantially parallel to the longitudinal axis of the telescoping boom assembly. The gripper in this Patent is rotated about its axis by a rotary actuator mounted within the  
30       forwardmost telescoping boom element and includes an hydraulically actuated linear-to-rotary converter.

35       One problem with the manipulator of U.S. Patent No. 3,916,701 and other prior art parts manipulators is that they are frequently large and heavy machines designed for industrial environments in which the handling of articles through precise programmed movements is required. For removal of molded parts from an injection molding machine, there is seldom

need for precision movement in engaging an article in the molding machine and removing the article to a remote work station such as a conveyor belt. There is also seldom need for high powered hydraulic actuator mechanisms since injection molded pieces typically are small, and lightweight when compared to comparably sized metal articles. Yet, flexibility in the sequence and extent of movement is a desirable feature of a manipulator.

Accordingly, there is the need for a simple, inexpensive, manipulator having movement and sequence flexibility and suitable for use in parts extraction from molding machines. Such a manipulator must successfully enter the space between the mold halves, engage or grasp the molded parts, retract the molded parts, and place the parts at a remote work station such as on a conveyor belt or the like.

An aim of the present invention is at least to mitigate the problems associated with prior art manipulators.

The present invention provides a workpiece manipulator, comprising: a base portion; an extensible arm mounted at one end to said base portion and comprising a plurality of tubular telescoping members extensible and retractable along a longitudinal axis; cable means, a first end region of which is housed within said telescoping members and attached to a said member, and a second, opposite, end region of which is attached for spooling about cable drum means; drum driving means for rotating said drum means in one direction for winding said cable means and in the other direction for unwinding said cable means, and to cause said arm to extend as said cable means unwinds and to retract as said cable means winds; and workpiece engaging means mounted to an upper end of said arm for engaging with a workpiece.

Desirably, the cable means acts to push an innermost one of said tubular members to extend said arm and pulls said innermost one of said tubular members to retract said arm. Said cable means preferably comprises a hollow elongate semirigid tube having sufficient compressive strength to support said arm, said workpiece engaging means, and a workpiece engaged thereby, when said arm is fully extended.

A preferred embodiment of the invention provides a workpiece manipulator especially suitable for engaging molded articles in a molding machine and for removing articles from the molding machine and placing them at a remote location, in which an extensible arm mounted to a base portion or slide box and comprising a plurality of coaxial tubular telescoping members extensible and retractable along a longitudinal axis is adapted to be extended and retracted by means of a cable or flexible hollow tube, which may be supported internally by a second smaller diameter flexible hollow tube, having compressive strength sufficient to support the arm when the arm is fully extended. The cable is housed within and supports the tubular members and has one end attached to the innermost one of the tubular members and the other end spooled about a cable drum. A motor is provided for rotating the drum in one direction for winding the cable to retract the arm, and for rotating the drum in the other direction for unwinding the cable to extend the arm. The manipulator further includes a workpiece-engaging assembly for engaging the workpiece or molded article in the mold and for carrying the article as the arm retracts.

The tubular members of the arm may have a rectangular cross-section, thus eliminating the need for a mechanism to prevent relative rotation between arm members which would be required for cylindrical arm members. Nevertheless, if arm rotation is desired for a particular application, the invention may be practised with cylindrical arm members.

A wrist swivel joint attached to the upper end of the arm and pivotable about a wrist bend axis which is perpendicular to the longitudinal axis of the arm mounts a workpiece-engaging assembly that is movable therewith for engaging the molded article in the mold and for pivoting to discharge the article. Preferably, the workpiece or article is engaged by one or more suction cups connected to a vacuum source which is selectively operable to impart suction to the suction cup for engaging and removing the articles and to release suction for discharging the articles.

Desirably, a carriage assembly, for supporting the base of the manipulator, is movable between a first position and a second position spaced apart from the first position. Driving means, for example a pneumatic cylinder, is provided for moving the base between the first

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position and the selectively adjustable second position. The carriage further includes a guide bar or rod upon which the base is mounted with supporting sleeves or bushings to guide the base smoothly between the first and second positions.

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The cable for extending and retracting the arm is preferably a pliant yet semirigid hollow elongate nylon tube further supported by a similar but smaller diameter nylon tube fitted coaxially within the larger tube. In this case, the workpiece manipulating assembly at the end of the arm includes a fluid connector to which one of the hollow nylon tubes is connected. The  
10 spooled end of the nylon tube is attached to a second fluid connector on the hub of the drum. A bore is provided in the axle of the drum and allows connection of a fluid source, such as air pressure or a vacuum, to the fluid connector, through the cable, and through the workpiece assembly fluid  
15 connector. Thus, the source of vacuum is conveniently provided through the cable through the fluid connectors and thence to the suction cups.

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By using a hollow cable to provide thrust and pull to the arm as well as to deliver vacuum to the workpiece-engaging assembly, the present invention facilitates the use of rectangular arm section members and eliminates the need for fluid-tight seals between arm members. Thus, the invention affords significant advantages in reliability and economy.

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A manipulator of the invention may further include a sequencing mechanism or controller responsive to the cycles of a molding machine for controlling the sequence of movements of the various elements of the manipulator. In particular, the sequencing controller is desirably responsive to the opening of the mold for providing an extraction signal, which causes the arm extending and retracting elements to extend the arm into the cavity between the mold halves. Thereafter, the sequencing controller causes the carriage to move forward, placing the suction cups upon the articles to be removed, and so actuates the vacuum source that the suction cups positively engage the articles. The carriage then retracts, and the arm also retracts, carrying the articles.

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When the arm has completely retracted, or has reached a desired level of retraction, the carriage can again be moved forward to move the

article engaged by the arm towards a work station, for example a conveyor belt. When the carriage has reached its desired extent of movement near the conveyor belt, the wrist swivel joint is caused to pivot, allowing the workpiece-engaging assembly to pivot downwardly towards a horizontal position, and the suction is then released thereby discharging the article onto the conveyor belt.

Thus, the invention also provides a method of removing articles from an article production machine using a manipulator, which method includes the steps of triggering a manipulator cycle at a predetermined point in the operating cycle of an article production machine, such as an injection molding machine, extending the telescoping manipulator arm carrying the workpiece-engaging device into a space between elements of the machine, moving the workpiece-engaging device into engagement with an article in the machine, removing the article by retracting the arm and the article, moving the manipulator arm and the article carried thereby towards a work station, and pivoting the workpiece-engaging device forward towards the work station and releasing the article.

Accordingly, it is an object of certain embodiments of the invention to provide an improved apparatus and method for removing articles from a molding machine.

It is another object of embodiments of the invention to provide an improved parts manipulator comprising a plurality of telescoping tubular members which can extend to engage an article in a confined space and can thereafter retract, carrying the article away from the confined space.

It is another object of certain embodiments of the invention to provide a telescoping parts manipulator which is lightweight, compact, and does not require complex and costly hydraulics or precision electrical actuators or position encoders in order to operate.

It is another object of embodiments of the invention to provide an improved telescoping parts manipulator including an arm which is caused to extend by the unwinding of a flexible yet compressively semirigid cable from a cable drum, and which is caused to retract by winding the cable onto

the drum, and it is a further object of embodiments of the invention to provide an improved telescoping parts manipulator whose arm retracts and extends by means of a cable which is also capable of carrying fluids from the base of the manipulator arm to the workpiece-engaging end of the manipulator arm.

In order that the invention may be more readily understood, and so that further features thereof may be appreciated, embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a cutaway pictorial perspective view of a telescoping parts manipulator of the present invention;

FIGURE 2 is a top plan partial cross-sectional view taken along the line 2-2 of Figure 1;

FIGURE 3 is a fragmentary side view of a suction cup wrist swivel workpiece-engaging assembly taken along the line 3-3 of Figure 1, with parts cut away;

FIGURE 4 is a partial left side cross-sectional view taken along the line 4-4 of Figure 2;

FIGURE 5 is a partial fragmentary cross-sectional view of a cable drum taken along the line 5-5 of Figure 2;

FIGURE 6 is a side view of an alternative scissoring 4-cup workpiece-engaging assembly;

FIGURE 7 is a rear view of the scissoring assembly shown in Figure 6;

FIGURE 8 is a schematic diagram of the sequencing controller;

FIGURE 9 illustrates the steps taken in removing an article from a mold and placing it on a conveyor belt;

FIGURE 10 is a fragmentary front view of another alternative 4-cup workpiece-engaging assembly; and

FIGURE 11 shows articles being placed on a double conveyor belt by a manipulator having the 4-cup workpiece-engaging assembly of Figure 10.

Referring now to the drawings, in which like numerals indicate like elements throughout the several views, Figure 1 shows a preferred embodiment of a telescoping parts manipulator 10 constructed in accordance with the present invention. The parts manipulator 10 includes a base portion or slide box 12, a section of which has been cut away in Figure 1 to show elements housed therein. A bottom panel 13 of the base portion 12 rests atop a base plate 14 and is adapted to slide thereacross using a slide box carriage assembly 75 which will be described below.

A telescoping extensible and retractable arm 15, comprising a plurality of tubular coaxial telescoping sections or members 20, 21, 22, 23, is attached to the bottom panel 13 of slide box 12 by means of brackets 25 and a rod 26 which extends through a lower region of the lowermost member 20. The arm 15 extends upwardly and away from the slide box 12 at a slight angle. Preferably, each of members 20 to 23 is aluminium, as is the slide box 12, for light weight. Guide sleeves 27, 28 (seen in Figure 4) of Teflon (Registered Trade Mark) or similar low-friction material are affixed by screws or the like to the upper end of each of the telescoping members to facilitate sliding movement of respective telescoping members and to serve as an extension stop by catching a flange affixed to the bottom of the above adjacent member. A typical flange 29 for the member 21 is seen in Figure 4.

Returning to Figure 1, a workpiece-engaging assembly 30 is mounted to the end of the uppermost arm member 23. The workpiece-engaging assembly comprises a pair of suction cups 31, 32 which are attached at opposite ends of an elongate horizontal mounting bar 33. The bar 33 is mounted to a pair of vertically-extending parallel stanchions 34, 35 which are in turn mounted for pivotable movement about a mounting block 36 by way of a shaft 37 which extends through both of stanchions 34, 35 and the mounting block 36. The mounting block 36 is affixed to the uppermost

member 23 with bolts or the like.

5 A double acting pneumatic cylinder PNI actuated by gas selectively delivered through hoses 24, 24a operates to cause the workpiece-engaging assembly 30 to pivot by means of a rack 40 and pinion 41 about an axis defined by shaft 37. The pinion 41 is fixed to and is co-rotatable with the shaft 37, the rack 40 engaging with the pinion 41. It will be appreciated that the stanchions 34, 35 and the mounting block 36 co-operate to define a wrist swivel joint perpendicular to the longitudinal axis of the arm 15, and  
10 pivotable between a first, substantially vertical position and a second, substantially horizontal position. It will also be appreciated that position control means such as a servomechanism and encoders can be employed at the end of the arm to provide accurate position control where required.

15 The workpiece-engaging assembly 30 is sized to fit between tie bars 44, 45 of a molding machine 46. A limit switch LSI, actuated by the opening of the mold of the molding machine 46, provides a signal which is used to trigger operation of the extension of arm 15 and the removal of molded articles from the molding machine by the suction cups 31, 32 of the  
20 workpiece-engaging assembly 30.

Still referring to Figure 1, the manipulator 10 further comprises an extending and retracting assembly 50 for extending and retracting the telescoping arm 15. The extending and retracting assembly 50 comprises a  
25 cable drum 51 supported on a shaft 56 within a housing block 52 that is in turn mounted to the bottom panel 13 of slide box 12 by bolting, welding, or the like. The cable drum 51 is helically grooved for spooling a cable 53 which acts to extend and retract the arm 15. Preferably the cable 53 is formed as a hollow outer tube 47 with a coaxial inner tube 48 (Figure 3)  
30 which conducts a fluid between the workpiece-engaging assembly 30 and the cable drum 51.

As best seen in Figures 2, 4 and 5, one end of the cable 53 is attached to a stemmed elbow 49 which, in turn, is attached to a fluid fitting 54  
35 mounted on an outer surface of a hub 55 of the drum 51. The cable 53 exits the housing block 52 through an opening 101 and thence enters the telescoping members 20 to 23 of arm 15. The cable is housed within the

5 telescoping members and terminates within uppermost member 23 at the mounting block 36. As will be described in detail later, the inner tube 48 of the cable 53 is in fluid communication with a hose 42 extending from the mounting block 36 to the bar 33. The bar 33 is hollow forming fluid passageways in communication with the suction cups 31, 32 and hose 42. The shaft 56 which supports the cable drum 51 within the housing block 52 also includes a bore which permits fluid communication between the stemmed elbow 49, the fluid fitting 54 and the hub 55. A fluid fitting 57 is provided at the end of shaft 56 and allows fluid communication through a hose 58 to a vacuum source. Thus, a vacuum may be applied to the suction cups 31, 32 through inner tube 48.

10 The angle of the arm 15 is adjustable by means of a rod 63 that extends between a support 64, mounted on the block 52, and a clevis 62 fixed to the arm 15. As will be described more fully below, rod 63 can be caused to extend or retract to cause arm 15 to pivot about the rod 26.

15 An electric motor M1 provides power for extending and retracting the arm. Motor M1 co-operates with a reduction drive 70 which reduces the speed of the motor M1 to provide an appropriate extension rate and torque for driving the cable drum 51. The reduction drive 70 and motor M1 are mounted to the bottom panel 13 of the slide box 12, for example by bolts, welding, or the like. A universal joint 72 with shear pins drivingly connects an output shaft of the reduction drive 70 to the shaft 56 of the cable drum. Shaft 56 is supported for rotation in housing 52 by bearing bushings 73, 74.

20 As mentioned above, the bottom panel 13 of the slide box 12 is adapted to move across the base plate 14 via a slide box carriage assembly 75. The carriage assembly 75 comprises a double acting pneumatic cylinder PN2 mounted to move the slide box 12 along the base plate. As best seen in Figure 2, an actuator rod 80 of the pneumatic cylinder PN2 is affixed by a bolt, or the like, to a support 81, which in turn is affixed to the base plate 14. The outer housing of cylinder PN2 is connected to a cylinder mount 82 which is rigidly affixed to a side wall or to the bottom panel 13 of the slide box 12. A pair of guide rods 83, 83', arranged parallel to the cylinder PN2 and mounted at each end by supports, 84, 85, 84', 85' to the base plate 14, ensure that the slide box 12 will move in a straight line across the base

plate. Each guide rod 83, 83' is slidably received in slide bushings 86, 87, 86', 87', made of TEFLON (Registered Trade Mark) synthetic resin polymer material or any other suitable low-friction material, which are mounted to the slide box 12. It will be understood that the slide box is able to move between a first or rearward position and a second or forward position or to any selected position therebetween.

Referring now to Figure 3, it may be seen that the upper end of cable 53 extends through the uppermost telescoping member 23. The outer tube 47 terminates at and is fixed to the mounting block 36 to communicate with a bore 92 formed through the mounting block. A connector 91, atop the mounting block 36, connects the bore 92 with the hose 42 which in turn is connected to bar 33. The connection of cable 53 to the mounting block 36 bears the thrust and pull of cable 53 to extend and retract arm 15. The connections of inner tube 48 and hose 42 are fluid tight to enable vacuum to be applied to the suction cup 32 and to the suction cup 31 (not shown in Figure 3).

The shaft 37 extends laterally through a second bore within the mounting block 36 with its ends fixed to stanchions 35 (and 34) and is rotatably supported by roller bearings fixed to the ends of the mounting box 36. Pneumatic cylinder PNI is fixed in spaced parallel relation to the arm member 23 by bracket 93 adjacent the mounting box 36.

The rack 40 is fixed to an actuator rod 98 of pneumatic cylinder PNI. Thus, as shown in Figure 3, by actuating pneumatic cylinder PNI to retract rod 98, as represented by arrow 94, the workpiece-engaging assembly 30 is caused to rotate, in the direction represented by arrow 95, to a new position shown at 30' in readiness to discharge a workpiece.

Referring to Figure 2, it may be seen that the cable 53 exiting the lower end of the arm 15 is guided into the housing block 52 via the opening 101 and thence winds about the cable drum 51. The opening 101 is laterally widened to accommodate the width of the helical grooves of the drum 51. It will be appreciated that the clearance between the edges of cable drum 51 and the housing block 52 is relatively small to contain the cable 53 within the grooves and ensure frictional contact between the cable

and the cable drum to minimize the risk of slippage as the drum unwinds the cable to extend the arm or winds the cable to retract the arm.

Figures 4 and 5 more clearly illustrate the pathway of the cable 53 through the opening 101 into the arm 15. The hub 55 of the drum 51 includes a radial bore 102 which opens into a mating radial bore in the shaft 56, and thence into an axial bore 103 provided in the shaft 56. O-rings 104 seal the juncture between the shaft 56 and the drum 51. It will be appreciated that a vacuum source or other fluid supply provided on hose 58 communicates with cable 53 through the fluid fitting 57, axial bore 103, radial bore 102, fluid fitting 54, and through stemmed elbow 49 into cable 53.

As best shown in Figure 4, the rod 63 for controlling pivoting of the arm 15 about rod 26 has a threaded rearward end extending through the rear wall of slide box 12. A knob 97 is so threaded onto rod 63 to abut the rear wall of the slide box 12 that turning of the knob 97 causes change in the relative angle of arm 15.

Figures 6 and 7 illustrate an alternative workpiece-engaging assembly 30a that comprises four suction cups 112 mounted in a cruciform arrangement suitable for engaging with four workpieces 113. A vertical mounting bar 120 and a horizontal mounting bar 121 are pivotably cross-mounted via a pivot pin 122 to a housing 123 for scissoring movement. A pneumatic cylinder PN3 is attached to the vertical mounting bar 120 and operatively connected to the horizontal bar 121. Upon actuation of pneumatic cylinder PN3, the horizontal mounting bar 121 pivots or scissors to the position shown at 121'.

The suction cups 112 carried by the horizontal mounting bar 121 are pivotably attached to the housing 123 by hubs 124 and a belt 125 so that upon the scissoring motion, the articles engaged by the suction cups maintain an orientation wherein their sides remain parallel to one another. The combination of scissoring of the horizontal mounting bar 121 and the pivoting of the workpieces carried by the suction cups on the horizontal mounting bar allows maintenance of clearance between workpieces and tie bars 44, 45 of the molding machine as the assembly 30a moves in the

direction of arrows 126. It will also be appreciated that such an arrangement allows for removal from the mold of four workpieces which otherwise might have required two separate removal operations. Therefore, the workpiece-engaging assembly 30a shown in Figure 6 allows utilization of more of the space between tie bars of a molding machine for placement of molds. Molds can be positioned directly above the tie bars, and the molded articles can be manipulated to avoid the tie bars upon removal from the mold. Furthermore, the workpiece-engaging assembly 30a may be adapted to manipulate any required number of workpieces.

In some prior art molded article removal systems, the space vertically above tie bars such as 44 and 45 was unusable for gravity-drop removal systems, and required manipulators with greater degrees of freedom (and consequently more complexity in cost) in order to manoeuver the molded articles immediately above the tie bars away from the tie bars to remove the articles from the space between the molding halves. The embodiment of the workpiece-engaging assembly 30a shown in Figure 6 therefore provides an inexpensive yet effective apparatus for removing molded articles from above tie bars.

Figure 10 shows a second alternative workpiece-engaging assembly 30b similar to the assembly 30 shown in Figure 1 but having four suction cups. Stanchions 34a and 35a extend upwardly and downwardly from the mounting block 36. Short hollow bars 154, 155 support suction cups 112 adjacent the lower ends of stanchions 34a and 35a. A three-way fluid connector 150 atop mounting block 36 distributes a vacuum to bars 33, 154, 152 and thence to suction cups 112. Pivoting of the assembly 30b is effected in the same manner as described above using a pneumatic cylinder and rack and pinion arrangement.

Figure 8 illustrates in schematic form a sequencing mechanism or controller usable in connection with a manipulator of the invention. Although as described above a limit switch LS1 provides an extraction signal upon the opening of the mold halves and a limit switch LS2 signals that arm 15 is fully retracted, it will be understood that the extraction and retraction signals can be obtained in various other means from the control devices for molding machinery. Whether limit switch signals or other signals obtained

from control devices of the molding machinery are used, they are input to a controller 130. Controller 130 may comprise digital logic circuits, relay logic, delay relays, pneumatic control logic, or other similar control methods known to those skilled in the art. The controller 130 provides signals on lines 131 to control the various motors and actuators used in the manipulator 10.

In response to an extraction signal, the controller 130 actuates the motor M1 to drive the cable drum and thus to extend the arm 15 into the space between mold halves (after an appropriate delay to ensure that the mold has completely opened before the workpiece-engaging assembly enters the space between the mold halves). The degree of extension of the arm 15 may be controlled by means such as a counter or a timer in controller 130 which runs the motor M1 for a sufficient period of time to allow the workpiece-engaging assembly 30 to reach the desired height. Those skilled in the art will understand how to adjust a timer for length extension adjustment of the arm. Those skilled in the art will also understand that a servomechanism drive may be provided for motor M1, together with encoder means attached either to the shaft of the cable drum or at other suitable points in the apparatus for feedback control, whereby absolute position control may be obtained for the length extension. It is therefore within the scope of the present invention to substitute for time delay devices an absolute position control feedback servomechanism for extension length control.

The controller 130 also provides control signals on lines 131 for actuating the workpiece-engaging assembly 30 and the slide box carriage assembly. Preferably the driving means are controlled by solenoid valves which control the supply of compressed air to pneumatic cylinders PN1 and PN2. A control signal drives a coil C1 of a first solenoid valve V1, which connects air from air supply means 132 to the pneumatic cylinder PN1. A check valve CV1 is provided to enable discharge of air from the valve V1 and cylinder PN1 in a conventional manner.

A solenoid valve V2 having a coil C2 is provided to enable control of the supply of air to the pneumatic cylinder PN2, for moving the slide box forwards and backwards on the base plate 14, and a check valve CV2 is

provided for discharge of air from the valve V2 and pneumatic cylinder PN2. A solenoid valve V3 having a coil C3 controls the provision of vacuum from a vacuum source 133 to suction cups 31, 32.

5        The controller 130 also provides a signal designated "ARM RETRACTING" on a line 135 to the molding machine control device, which serves as a safety signal to ensure that the mold does not close for a new molding cycle until the arm has cleared the molding machine.

10        Operation

15        Figure 9 illustrates an operating sequence utilized by a manipulator of the invention. As illustrated at step A, the opening of the molding machine 46 actuates limit switch LSI, providing an extraction signal to the controller 130 to initiate a removal operation. (Step A incidentally also shows the relative position of elements on completion of the last step of an operating sequence wherein a molded article 5 is deposited on a conveyor belt 6 and the workpiece-engaging assembly 30 subsequently returns to its first or substantially vertical position).

20        As shown at step B, the arm 15 extends until the workpiece-engaging assembly 30 enters the space between mold halves 140, 141 and a suction cup 31 is positioned in proximity to a molded article 5 contained in the mold.

25        Subsequently, as shown at step C, pneumatic cylinder PN2 is actuated, driving the slide box 12 forward and causing the suction cup 31 to engage the molded article 5. In some applications, the forward movement of the slide box can accompany the extension of the arm, provided that obstacles are avoided and adequate contact is made with the molded article.  
30        When the suction cup has engaged the article, suction is provided so that the molded article will adhere to the suction cup.

35        At step D, prior to the closing of the mold, the arm 15 is retracted, carrying the molded article 5 and clearing the tie bar 45 of the molding machine 46. As soon as the molded article 5 has cleared the tie bar 45, the molding machine can begin a new molding cycle. The signal "ARM

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RETRACTING" can then be provided by the controller 130 to so signal the molding machine that a new molding cycle may be initiated. Also at step D, the slide box 12 is retracted from its second or forward position back towards the first or rearward position. It will be appreciated that in some applications, the retraction of arm 15 and the retreating movement of the slide box 12 can occur simultaneously, provided that the workpiece-engaging assembly 30 and any articles carried thereby clear the parts of the molding machine.

At step E, the molding machine has closed to begin another molding cycle. Arm 15 reaches its fully retracted position, and pivoting movement of the workpiece-engaging assembly 30 is initiated for release of the molded article 5 onto the conveyor belt 6.

At step F, the slide box 12 again moves forward from the rearward position to the forward position for release of the article 5 onto the conveyor belt 6. It should be understood that the pivoting of the workpiece-engaging assembly 30 and the movement of the slide box 12 towards the conveyor belt 6 may occur simultaneously, provided that the molded article is satisfactorily deposited upon the conveyor belt 6. After the workpiece-engaging assembly 30 has pivoted and placed the molded article on the conveyor belt 6, suction is released and the workpiece-engaging assembly pivoted upright as shown in step A so that the manipulator is ready for the mold opening for a new cycle.

The alternative workpiece-engaging assembly 30b shown in Figure 10 is particularly suitable for operation in connection with a double conveyor belt. To illustrate, Figure 11 shows the final step of operation in a sequence similar to that illustrated in Figure 9. Belts 6a, 6b are parallel and spaced apart, straddling the arm 15. When arm 15 retracts, workpieces 5 are simultaneously discharged onto belts 6a and 6b.

# CLAIMS

1. A workpiece manipulator, comprising: a base portion, an extensible arm mounted at one end to said base portion and comprising a plurality of tubular telescoping members extensible and retractable along a longitudinal axis; cable means, a first end region of which is housed within said  
5 telescoping members and attached to a said member, and a second, opposite, end region of which is attached for spooling about cable drum means; drum driving means for rotating said drum means in one direction for winding said cable means and in the other direction for unwinding said cable means, and to cause said arm to extend as said cable means unwinds and to retract as  
10 said cable means winds; and workpiece engaging means mounted to an upper end of said arm for engaging with a workpiece.
2. A manipulator according to claim 1, wherein the first end of said cable means is attached to an innermost one of said tubular members.
- 15 3. A manipulator according to claim 1 or 2, wherein said cable means acts to push an innermost one of said tubular members to extend said arm and pulls said innermost one of said tubular members to retract said arm.
- 20 4. A manipulator according to claim 1, 2 or 3, wherein said cable means comprises a hollow elongate semirigid tube having sufficient compressive strength to support said arm, said workpiece engaging means, and a workpiece engaged thereby, when said arm is fully extended.
- 25 5. A manipulator according to claim 4, further comprising first fluid connector means attached to said workpiece engaging means and in fluid communication with the inside of said first end region of said tube, second fluid connector means attached to said cable drum means and in fluid communication with the inside of said second end region of said tube, and  
30 fluid driving means operatively connected to said cable drum means for providing a fluid flowpath through said second connector means, said tube, and said first connector means to said workpiece engaging means.

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6. A manipulator according to claim 5, wherein said fluid driving means comprises a vacuum source, wherein said workpiece engaging means comprises at least one suction cup for engaging with a surface of a workpiece, and wherein said vacuum source is selectively operable to impart suction to said suction cup for engaging and removing the workpiece and for releasing suction for discharging the workpiece.

7. A manipulator according to any one of claims 1 to 6, further comprising a wrist swivel joint formed at the upper end of said arm and pivotable about an axis perpendicular to said longitudinal axis of said arm, and first driving means for pivoting said workpiece engaging means and said wrist swivel joint.

8. A manipulator according to claim 7, wherein said workpiece engaging means is mounted to said wrist swivel joint and movable therewith for engaging the workpiece in a first plane and for discharging the workpiece in a second plane.

9. A manipulator according to claim 7 or 8, wherein said first driving means comprises a pneumatic cylinder.

10. A manipulator according to claim 7, 8 or 9, wherein rack and pinion means are operatively connected to said first driving means for pivoting said wrist swivel joint and said workpiece engaging means.

11. A manipulator according to any one of claims 1 to 10, further comprising carriage means for supporting said base portion, said base portion being capable of moving between a first position and a second position spaced apart from said first position, and second driving means for moving said base portion between said first and said second positions.

12. A manipulator according to claim 11, wherein said carriage means comprises at least one track bar, wherein said base portion is mounted to said track bar with supporting sleeves, and wherein said second driving means comprises a pneumatic cylinder mounted for driving said base portion between said first position and said second position.



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5 13. A manipulator according to any one of claims 1 to 12, further comprising sequencing means responsive to the cycles of a molding machine for providing an extraction signal at a predetermined time during a molding machine operating cycle, and control means responsive to said extraction  
10 10 signal for providing an extend-arm signal at a first predetermined time during a molding machine cycle and a retract-arm signal at a second predetermined time during said molding machine cycle, and wherein said drum driving means is responsive to said extend-arm signal for extending said arm to engage the workpiece, and is thereafter responsive to said  
15 retract-arm signal for retracting said arm and the workpiece to remove the workpiece from the molding machine.

14. A manipulator substantially as described herein with reference to, and as shown in, Figures 1 to 5 of the accompanying drawings.

15 15. A manipulator according to claim 14, modified substantially as described herein with reference to, and as shown in, Figures 6 and 7 of the accompanying drawings.

20 16. A manipulator according to claim 14, modified substantially as described herein with reference to, and as shown in, Figures 10 and 11 of the accompanying drawings.

25 17. A method of removing articles from an article production machine using a manipulator according to any one of the preceding claims, which method includes the steps of triggering a manipulator cycle at a predetermined point in the operating cycle of an article production machine, extending the telescoping manipulator arm carrying the workpiece-engaging device into a space between elements of the machine, moving the work-  
30 piece-engaging device into engagement with an article in the machine, removing the article by retracting the arm and the article, moving the manipulator arm and the article carried thereby towards a work station, and pivoting the workpiece-engaging device forward towards the work station and releasing the article.

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\* C L M S \*