

[54] **FLUID-OPERATED ACTUATOR**

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[56] **References Cited**

UNITED STATES PATENTS

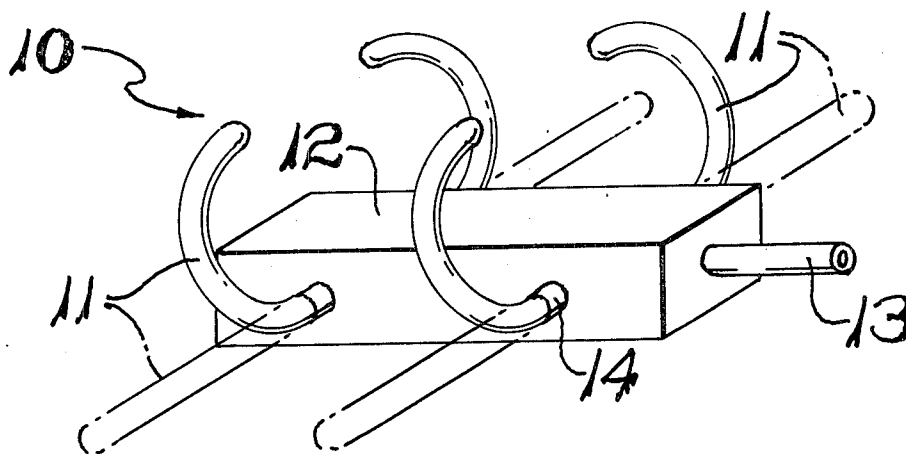
3,601,442	8/1971	Orndorff.....	294/99
3,343,864	9/1967	Baer	294/99
1,693,074	11/1928	Falco	294/112

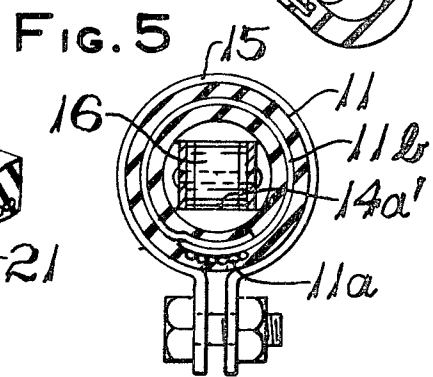
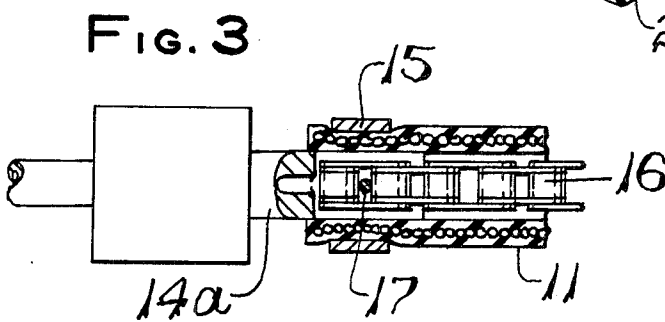
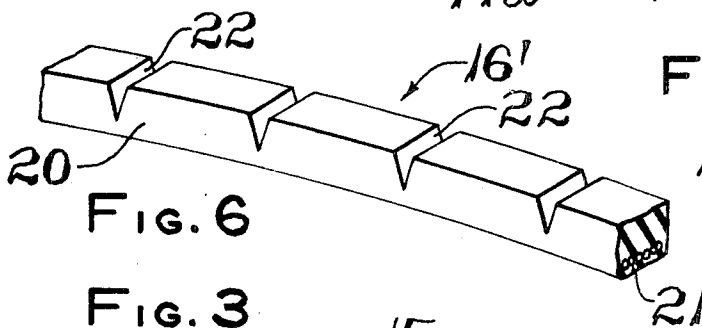
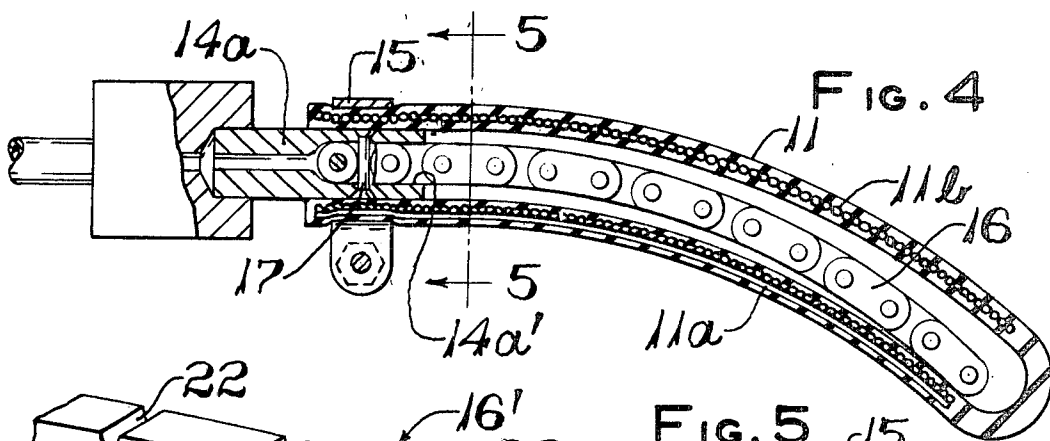
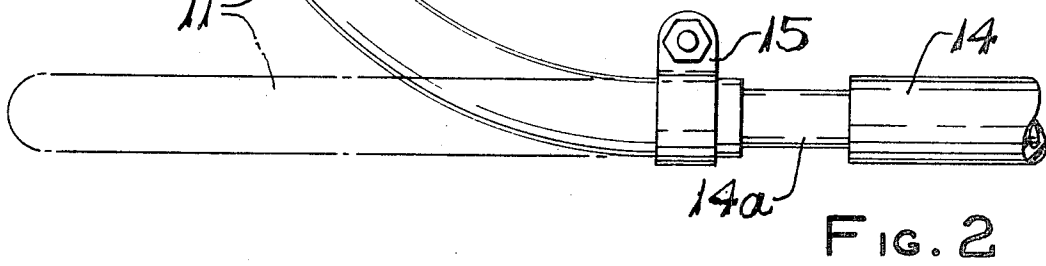
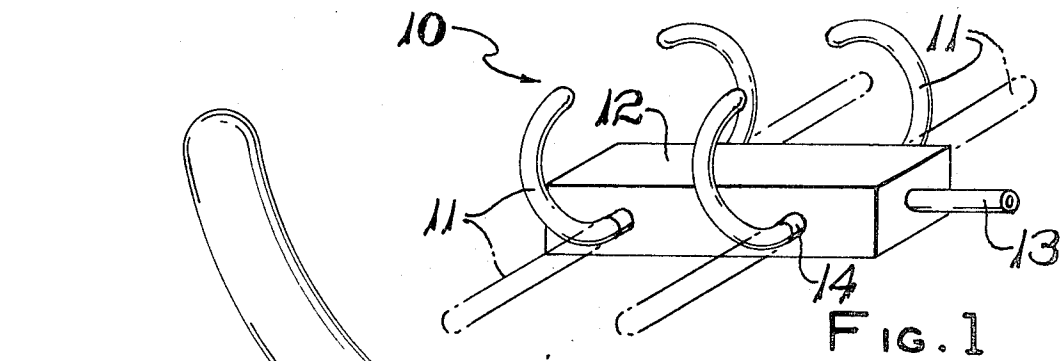
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[57] **ABSTRACT**

An actuator comprising a flexible elastomeric tube, which curls when one end is closed and the other end is connected to a fluid pressure source and has a uniplanarly flexible member provided in the bore of the tube and disposed so as to permit flexing of the tube only in a single plane. The tube preferably has an elongated longitudinal member of inextensible material embedded in the wall of the tube so as to extend transversely for less than one-half the tube periphery and so that the plane of curling includes the flexible member and the tension member. One embodiment includes a plurality of such tubes connected to a common manifold such that each tube curls about its respective tension member toward a central region for grasping an object.

7 Claims, 6 Drawing Figures





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FLUID-OPERATED ACTUATOR

BACKGROUND OF THE INVENTION precise, grasping

In the design and manufacture of fluid pressure operated actuators, it has long been desirable to provide an actuator, of the type having a flexible "finger" of elastic material extending from a source of fluid pressure in which the finger would be capable of precise, predictable and controllable motion in a single plane. This is particularly desirable where a plurality of such fingers have been interconnected to a common pressure manifold for curling toward a central region for grasping an object.

Heretofore, various expedients have been tried, generally unsuccessfully, to provide such an actuator, examples of which include pivoted links actuated by fluid pressure power cylinders connected to the links and flexible curling tubes having portions of the tube containing greater amounts of material to permit extension of one side of the tube upon internal pressurization. An example of this latter type of actuator is found in the Baer U.S. Pat. No. 3,343,864, wherein a plurality of tubes is attached to a common pressure manifold with one side of each tube corrugated for the length of the tube such that, upon internal pressurization, the corrugated side of the tube wall extends longitudinally an amount greater than the remaining portion of the tube, thus causing the tubes or fingers to curl about a central region and provide for grappling or grasping an object therein.

In the former-type actuator, the pivoted links, power cylinders and associated hardware have rendered these devices rather complex and costly. For applications where small size is required, in addition to portability and lightness in weight, the pinned linkage-type actuator is generally considered too heavy and cumbersome and therefore unsuitable.

Moreover, where it is desired to provide large magnitude gripping forces in actuators of the flexible finger type having a partially corrugated tube wall for providing the flexibility and curling of the fingers, it has been quite difficult to fabricate a "finger" of this type capable of withstanding the higher pressures required for gripping heavier objects. Moreover, the motion of such corrugated fingers is somewhat erratic and imprecise in view of the difficulty in providing a corrugated tube structure which has uniform extension qualities and which responds accurately and repeatably to variations in pressure. Experience has shown that the curling motion of the corrugated fingers often exhibits an axial lead or helical pitch rather than curling in a single plane. Furthermore, fingers of this type are readily subject to undesirable lateral or helical deflection by contact with other objects or by the application of external lateral forces. Therefore, in those applications, as for example precision remote-control material-handling devices, where precise planar curling of the fingers is required, actuators of the type having no restraint against helical motion are generally unsuitable. Thus, it has been desirable to devise an actuator of the type having elastic fingers which curl upon internal pressurization, with the fingers restrained to curl in a single plane and one in which the fingers are capable of being precisely controlled in the degree of curling and further capable of repeating successively, with precision, a specified amount of curling motion for gripping or actuating other mechanisms.

SUMMARY OF THE INVENTION

The present invention provides a solution to the above-described problem by providing an actuator having a flexible finger of elastic material which is initially linear, but, upon introduction of pressurized fluid therein, curls toward a central region to grasp an object and preferably has a uniplanar flexible member inserted in the bore of the tube to limit the curling to a single plane. Preferably, the finger has a longitudinally extending tension-resistant member embedded in the tube wall which member extends transversely less than one-half the periphery thereof and is so located that a radial plane passing through the tension-resisting member contains the

plane of curling. In one embodiment of the invention, a common roller chain is used in the bore of the tube to prevent helical curling and in another embodiment a transversely serrated strip of reinforced elastomeric material is used.

A plurality of such fingers may be attached to a common pressure manifold to form a gripping device capable of having its fingers each curl in controlled motion in a single plane since the uniplanar flexible member in the bore of each tube prevents axial or helical lead while the finger is curling. The structure of the present actuator thus produces precisely repeatable motion for the finger upon successive pressurization and depressurization cycles.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one embodiment in which a plurality of actuator fingers are connected to a manifold and which are illustrated in the curled position in solid outline and in phantom outline in the initial or relaxed position;

FIG. 2 is a side view of one of the fingers of the embodiment of FIG. 1 showing the attachment to the manifold with the actuated state shown in solid outline and the initially relaxed state shown in phantom outline;

FIG. 3 is a fragmentary top view of the actuator of FIG. 2 with a portion of the tube broken away to show the roller chain in the bore of the tube;

FIG. 4 is a side view of the finger of FIG. 3 showing the roller chain in the curved position;

FIG. 5 is a sectional view taken along section indicating line 5—5 of FIG. 4 and shows the details of the reinforcing member in the tube wall; and,

FIG. 6 is a perspective view of a portion of an alternate form of the uniplanar flexible member.

DETAILED DESCRIPTION

Referring now to FIG. 1, the presently preferred form of the invention is shown embodied in an actuator 10 shown as comprising a pressure manifold 12 of metal or other rigid material having a pressure chamber therein and an inlet port 13 communicating with the chamber. A plurality of spaced transfer ports 14 are provided in the manifold with each transfer port communicating with said pressure chamber. A plurality of actuator fingers 11 formed of tubing of elastomeric material is provided with one of the said tubes connected to each of the transfer ports 14. The free end of the tube 11 is closed in a pressure sealing manner.

Referring now to FIG. 2, each tube 11 is received over a nipple 14a extending from the transverse port 14 and a clamp 15 is provided over the tubing to provide a fluid pressure sealing connection. It will be understood, however, that other means for attaching the tube to the nipple as, for example, vulcanizing may be used in place of clamping. In the unpressurized state, the tubes have the rectilinear position shown in FIG. 1 by a phantom outline. When pressurized, the tubes curl about a central region as shown in solid outline in FIG. 1.

Referring now to FIG. 5, the presently preferred construction of each of the tubes 11 is shown as comprising a longitudinally extending strip 11a of substantially inextensible but flexible material embedded in the reinforced elastomeric wall of the tube which strip extends less than one-half the periphery of the tube. In the presently preferred practice of the invention, the strip 11a comprises a plurality of inextensible, weftless, textile cords embedded in the elastomeric material of the tube however, the strip may be formed of a homogenous layer of flexible but inextensible material as, for example, metal rather than a plurality of textile cords. The tube 11 preferably has at least one layer of circumferentially disposed inextensible cords 11b embedded in the wall radially inwardly of the tension cords 11a with the cords 11b circumferentially overlapping in a region of the tension cords 11a. The construction is such that, upon pressurization, each tube curls about the side having tension cords 11a therein. Therefore, in order to provide a gripping action, it is required that

the tubes be connected to the transverse ports 14 with the tubes arranged such that the tension members 11a are adjacent a common side such that the tubes will curl toward a common central region.

Referring now to FIG. 4, each of the tubes is shown as having a uniplanar flexible stiffening member 16 extending in the bore of the tube, which member 16 is preferably attached to the nipple 14a of the transverse port and thus extends in cantilever into the bore of the tube 11. In the embodiment of FIGS. 3 and 4, the uniplanar flexible member 16 comprises a roller chain having one end received in a slot 14a' formed in the end of the nipple 14a and the chain is secured in the slot by a pin 17 received transversely through the nipple and passing through one of the spaced intermediate adjacent rollers of the chain. The chain is disposed such that it flexes about an axis perpendicular to the length of the tube thus restricting the direction of the curling of the tube 11 to that of the flexure plane of the chain. The chain is oriented such that the flexure plane passes through the longitudinal centerline of the tension member in the tube wall. The free end of the chain extends in close proximity to the closed end of the tube 11 and the chain rests along the bore of the tube. FIG. 4 shows the position of the chain when the tube 11 is pressurized.

Referring now to FIG. 6, an alternate embodiment of the flexible member 16' is shown as transversely serrated reinforced elastomeric strip 20. The strip has a plurality of tension-reinforcing cords 21 embedded therein adjacent one side thereof and a plurality of spaced transverse notches or serrations 22 formed in the strip 20 in the side opposite the reinforcing cords. The strip is thus capable of flexing freely in only one plane by virtue of the lateral stiffness imparted thereto by the layer of reinforcing cords. Furthermore, flexing is limited in the direction tending to close the serrations by virtue of contact of portions adjacent the serrations; whereas, flexing in a direction tending to further open the serrations is more freely permitted. The strip 20 is disposed in the tube bore with the reinforcing cords adjacent the side about which curling is desired. The embodiment of the stiffening member 16' of FIG. 6 thus serves in the same manner of roller chain 16 in the embodiment of FIGS. 3 and 4.

The present invention thus provides an actuator having at least one and preferably a plurality of initially straight actuator fingers which upon introduction of fluid pressure therein curl toward a central region to provide gripping or grasping of an object. Each of the fingers has a uniplanar flexible stiffening

member provided in the tube bore such that the fingers are capable only of curling in a single plane and thus provide precisely controllable and repeatable motion.

Modifications and adaptations of the described and illustrated embodiments of the invention will be apparent to those having ordinary skill in the art and the invention is limited only by the spirit and scope of the following claims

I claim:

1. A fluid pressure operated actuator comprising:

- a. a closed-end flexible tube having longitudinally extending regions of different extensibilities such that the tube curls about an axis substantially perpendicular to its length when fluid pressure is applied to the interior of the tube; and
 - b. an elongated stiffening member disposed in the bore of said tube, the said member being capable of flexing in only a single plane and arranged with the said plane of flexure coinciding with the said plane of curvature of the tube.
2. The actuator defined in claim 1, wherein said stiffening member has one end anchored within the tube at a location remote from the closed end and the remaining end free.
 3. The actuator defined in claim 1, wherein said stiffening member is a roller chain.
 4. The actuator defined in claim 1, wherein said flexible member includes a generally flat strip of elastomeric material reinforced with a layer of longitudinally extending cords embedded adjacent one face thereof with the opposite face having a plurality of longitudinally spaced transverse serrations formed therein.
 5. The actuator defined in claim 1, wherein said tube is formed of elastomeric material with a layer of circumferentially extending substantially weftless reinforcing cords embedded in the wall thereof.
 6. The actuator defined in claim 1, wherein one of said regions of different extensibility includes a plurality of substantially inextensible longitudinally extending weftless cords.
 7. The actuator defined in claim 1 in combination with:
 - a. a fluid pressure manifold having a plurality of transfer ports thereon; and wherein
 - b. one of said tubes is attached to each of said transfer ports with the tubes extending radially outwardly therefrom with the planes of curling of said tubes oriented such that upon pressurization they curl about an object adjacent thereto.

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