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Delson et al.

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[54] **ACTUATOR WITH OPPOSING REPULSIVE MAGNETIC FORCES**

[75] Inventors: **Nathan J. Delson**, Branford, Conn.;
John S. Houston, New York, N.Y.

[73] Assignee: **Coactive Drive Corporation**,
Brookline, Mass.

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[51] Int. Cl.⁶ **H02K 41/00**; G06F 17/00

[52] U.S. Cl. **310/14**; 273/148 R; 341/20

[58] Field of Search 310/12, 13, 14,
310/17, 23, 28, 75 R, 112; 273/148 R;
341/20; 901/2, 15; 74/471 R

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Primary Examiner—Nestor Ramirez

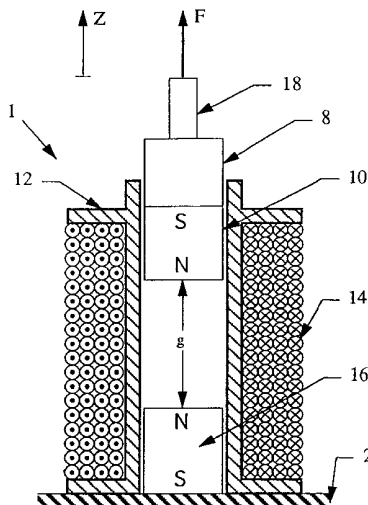
Assistant Examiner—Judson H. Jones

Attorney, Agent, or Firm—Steven J. Weissburg

[57] **ABSTRACT**

A new class of actuators and mechanisms use opposing repulsive magnetic forces. The repulsive forces are typically generated between a stationary magnet and a moving magnet, where the moving magnet is coupled to the mechanism output member. The mechanisms are generally configured such that the repulsive force from one electromagnet is opposed by a repulsive force from another electromagnet, where the opposing forces are simultaneously applied to the mechanism's output member. This configuration is similar in certain aspects to the way biological flexor and extensor muscles are configured in a musculoskeletal system. The opposing configuration allows for open loop control of position and stiffness. The actuator mechanism may have both rotary and linear motion output, and may have either a single degree of freedom or multiple degrees of freedom. Permanent magnets can be used to create a baseline repulsive force without electric power, and electromagnets can modulate the repulsive force magnitude. The actuator can provide high fidelity motion and force output, and is well suited for human interface devices, such as force feedback joysticks. Other applications include adjustable stiffness devices, and high bandwidth mechanisms.

35 Claims, 39 Drawing Sheets



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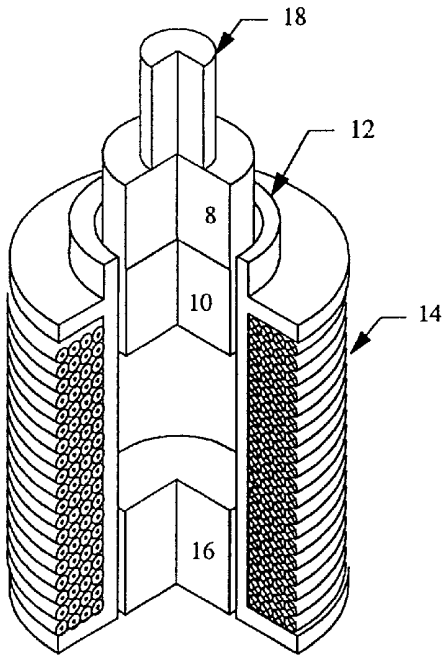


Fig 1

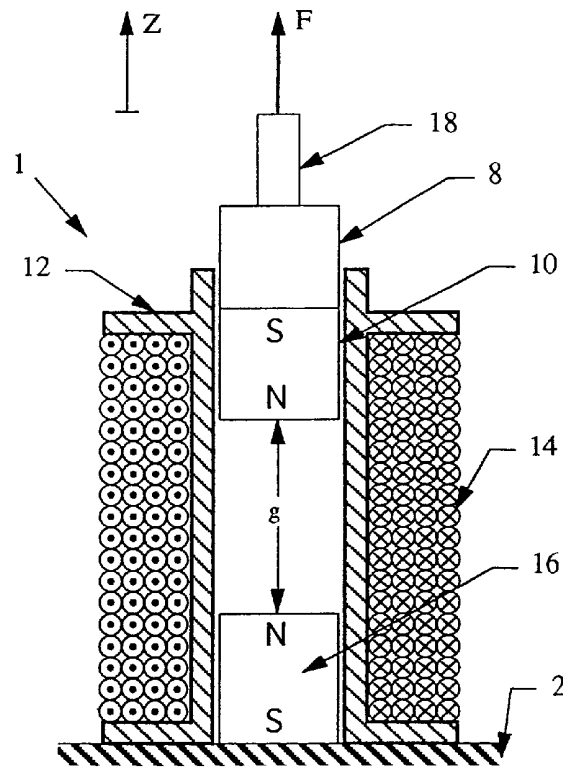


Fig 1A

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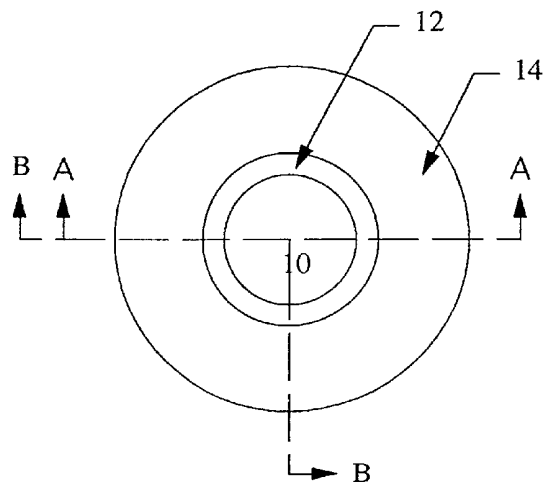


Fig 1B

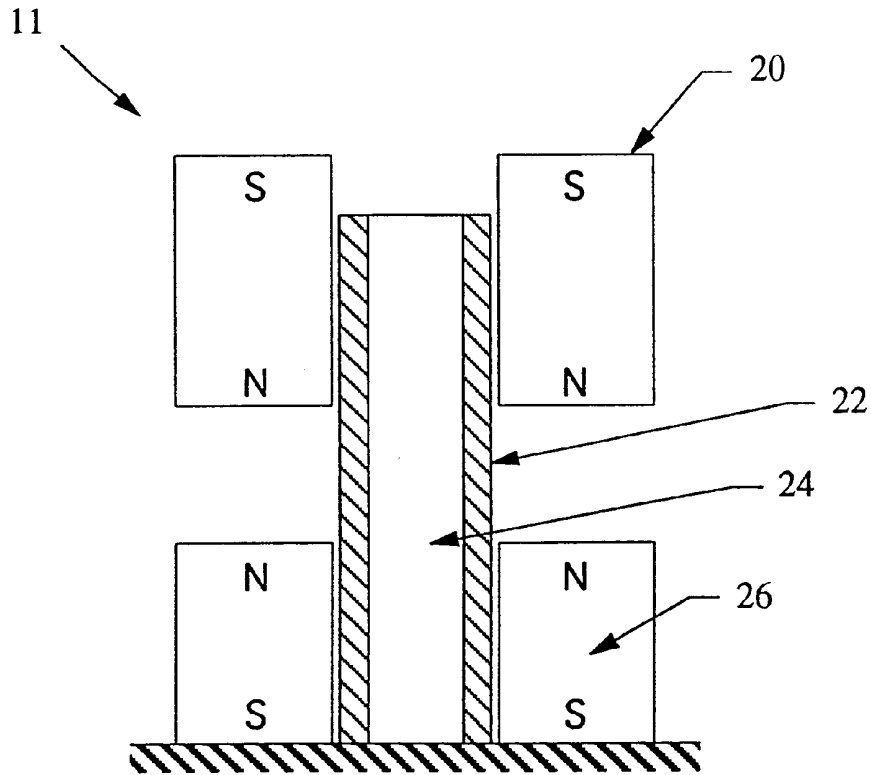


Fig 2A

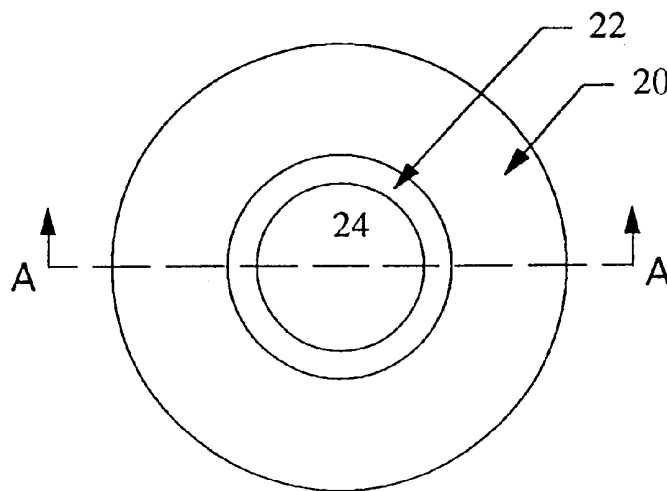


Fig 2B

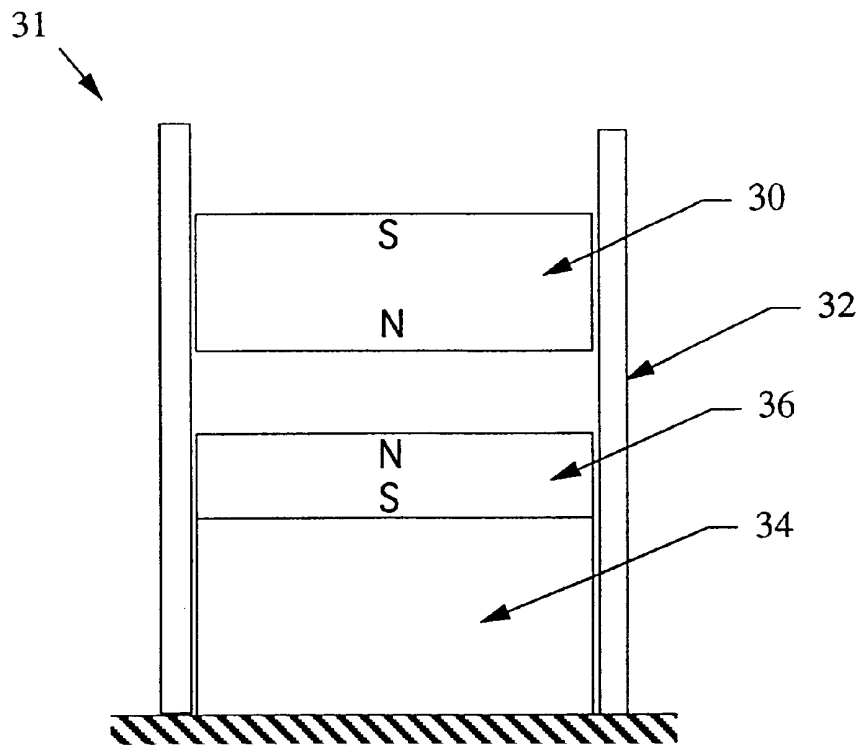


Fig 3A

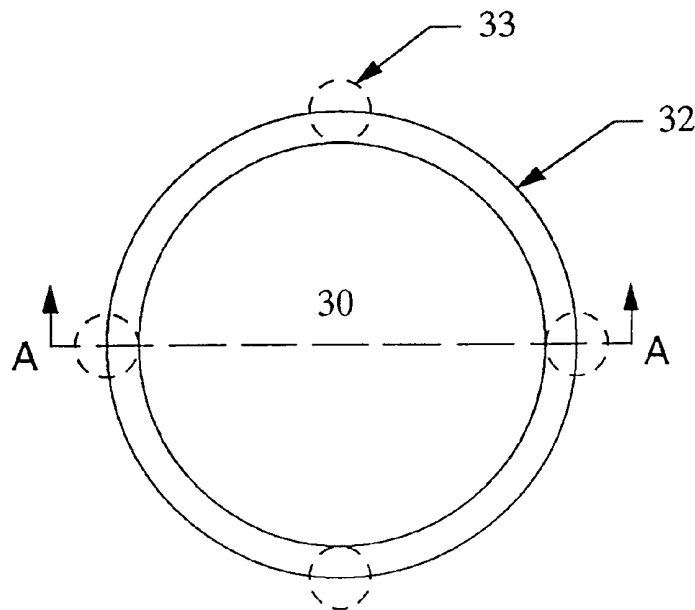


Fig 3B

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