prising a non-differential linear actuator **350** that includes a shell **352** and a movable piston **354** connected to a piston rod **356**. Seals **358**, **359**, and **360** seal fluid chambers **362** and **364** on opposing sides of the piston **354**. The fluid chambers **362** and **364** are connected by a suitable fluid passage **366**. An orifice **368** limits the flow rate in the fluid passage **366**. The resistance to flow created by the orifice **368** is determined by the size of the orifice and the viscosity of the fluid flowing through the orifice. A magneto-rheological fluid comprises generally a carrier, such as water, oil, or silicone, and suspended particles of magnetic material, known as carbonyl iron. The viscosity of a magneto-rheological fluid can be varied by altering the strength of a magnetic field applied to the fluid. In the actuator **350**, the voltage in a coil **370** adjacent to the orifice **368** is controlled by the controller **98** to regulate the viscosity of the magneto-rheological fluid that is transferred from one fluid chamber **362** to the other **364** by the piston's displacement. When the lever **88** is rotated, the filament **304** attached to the lever and the piston rod **356** causes the piston **354** to be displaced in the shell **352**.

[0059] Alternatively, a piezoelectric flextensional transducer or an electroactive polymer transducer **400** may be applied as illustrated in **FIG. 8**. A typical piezoelectric unimorph comprises a single piezoelectric element externally bonded to a flexible metal foil which is stimulated by the piezoelectric element when activated with a changing voltage. This produces axial buckling or deflection as foil opposes the movement of the piezoelectric element. The actuator movement for a unimorph can be either contraction or expansion. A piezoelectric bimorph device includes an intermediate flexible metal foil sandwiched between two piezoelectric elements bonded to a plate. Electrodes are bonded to each of the major surfaces of the ceramic elements and the metal foil is bonded to the inner two electrodes. A multilayer device known as a multimorph can be made by stacking alternating layers of ceramic elements and metal plates. When a voltage is applied to the electrodes, the bimorph or multimorph bends. Bimorphs and multimorphs exhibit more displacement than unimorphs because under the applied voltage, one ceramic element will contract while the other expands. Deflection of the electroactive polymer transducer or the piezoelectric unimorph, bimorph or multimorph transducer **400** linked by the filament **402** to the lever **88** and anchored **404** to the lever **86** can be used to exert force to resist or assist flexing to the levers of the bracing elements.

[0060] The contractile and sensing transducers of the adjustable orthotic brace may comprise polymer-metal composite actuators and sensors. An ionic polymer-metal composite (IPMC) comprises a polymer having ion exchanging capability that is first chemically treated with an ionic salt solution of a conductive medium, such as a metal, and then chemically reduced. An ion exchange polymer refers to a polymer designed to selectively exchange ions of a single charge with its on incipient ions. Ion exchange polymers are typically polymers of fixed covalent ionic groups, such as perfluorinated alkenes, styrene-based, or divinylbenzene-based polymers. Referring to **FIG. 11, a** simple polymer-metal composite acutator or sensor **600** comprises suitable electrodes **602**, **604** attached to a polymer-metal composite element. When a time varying electric field is applied to the electrodes **602**, **604** attached a polymer-metal composite element **606**, the element will exhibit a large dynamic deformation **606'**. Referring to **FIG. 12**, an embodiment of an adjustable orthotic brace comprises a bracing element **650** including upper **652** and lower **654** levers joined with a pivot **656** at their distal ends. A polymer-metal composite transducer **658** is used to control the force required for relative rotation of the upper **652** and lower **654** levers or to sense the rotational displacement of the levers. A voltage applied to the electrodes **660**, **662** of the transducer **658** through wires **664** causes the polymer-metal composite element **668**, which is restrained to the brace levers **652**, **654** by mounting blocks **670**, **672**, respectively, to deflect. The deflection of the polymer-metal composite element **668** can be used to either aid or resist rotation of the levers **652**, **654** according to a treatment regimen.

[0061] On the other hand, when such a polymer-metal composite element **606** undergoes dynamic deformation, a dynamic electric field is produced across the electrodes **602**, **604** attached to the composite element. If the voltage at the electrodes **660**, **662** of the transducer **658** is measured when the polymer-metal composite element **668** is deflected, the force being exerted on the levers **652**, **654** can be measured.

[0062] Feedback to the controller **98** is provided by a sensing transducer **144** such as a strain gage at the attachment of a loading transducer or the filament **140** to a lever **86** or **88** of the bracing element **84**. The controller **98** can vary the force exerted by the loading transducer **140** throughout the range of motion of the joint by executing program instructions relating the position of the levers as sensed by the shaft encoder **127** and the force generated by the loading transducer as determined by the sensing transducer **142**.

[0063] Another embodiment of an adjustable brace comprises an elastic sleeve incorporating loading and sensing transducers. A sleeve is an expandable, slip-on device that typically comprises nylon-covered neoprene. While sleeves are simple, easy to fit, and relatively inexpensive, a simple sleeve cannot apply leverage to the joint which is necessary for ligamentous support and lessening the likelihood of joint injury. Referring to **FIG. 10**, the adjustable orthotic elbow sleeve **500** comprises an insulating neoprene shell **502** confining portions of the upper arm, the lower arm, and the elbow. The shell **502** compresses the soft tissue of the arm and elbow and keeps the joint warm. A covering for the shell **502** comprises a mesh **504** of interconnected electroactive polymer filaments **506**. A first plurality of electroactive polymer filaments is arranged circumferentially around the sleeve **505** and a second plurality of filaments is aligned generally longitudinally **507**. A third plurality of filaments **506** are arranged on a bias to the axes of the limb elements **508** and **509** and a fourth plurality of the filaments **510** are arranged at second bias to the axis of the limb elements and at a bias to the fibers of the third plurality. The lengths of the electroactive polymer filaments **506** are responsive to a voltage applied to electrodes on the surfaces of the filaments by a driver controlled by a controller **98**. As the lengths of the circumferential filaments **505** are changed, the sleeve is tightened and loosen on the limb and as the lengths of the longitudinal filaments of the second plurality are changed force can be applied to assist or resist flexion and extension of the joint. As the length of a biased filament changes, the connected neighboring filaments are either tightened and pulled together or loosened and allowed to separate. Increasing the tensioning of the filaments **506** tightens the sleeve