[0069] The following comprises a number of different embodiments employing the teachings of the present invention. Where elements are substantially the same as those discussed above, they are given the same reference numeral. Based on the variety of mechanisms utilized by various manufacturers to reduce the movement of a haptic interface device into manageable and measurable components, such as movements in an x-direction and a y-direction, numerous configurations of haptic interface systems utilizing the teachings of this invention may be employed. Thus, these examples are not intended to be limiting, but are exemplary of the teachings of the present invention to numerous embodiments of haptic interface systems.

[0070] In general, the movement of a haptic interface device **26** is either linear or rotary, which includes partial rotation or curvilinear motion. Similarly, a magnetically-controllable device **24**, as mentioned above, is capable of providing opposing variable resistance force to either linear or rotary movements, including partial rotation or curvilinear motion. To control the movements of the haptic interface device **26**, the magnetically-controllable device **24** must somehow be linked to the haptic interface device **26**. As such, the linking mechanisms typically translate the following types of movement from the haptic interface device **26** to the magnetically-controllable device **24**: linear to linear; linear to rotational; rotational to rotational; and rotational to linear. Hence, the configuration of the haptic interface unit may vary, and the configuration of the magnetically-controllable device **26** may vary, depending on: the mechanisms used to resolve the movement of the haptic interface device **26**; space constraints; resistance force and/or torque requirements; and cost constraints. Therefore, the teachings of the present invention may be applied to a plurality of different configurations with equal success.

[0071] Referring to **FIG. 3**, one embodiment of the present invention comprises haptic interface unit **55** having a magnetically-controllable device **24** that is adapted to apply resistance forces to haptic interface device **26** through drive mechanism **92**. In **FIG. 3**, the interface device is a steering wheel which is shown for use in **FIG. 1C** in a vehicle. In such an application magnetically controllable device **24** is a rotary brake and monitor **30** displays vehicle operating information. Drive mechanism **92** may be driven by an operator **22** (See **FIG. 1C**.) in operable contact with haptic interface device **26**, such as the steering wheel shown. Sensor **32** is in rotary contact with drive mechanism **92** to determine and report the position of the drive mechanism, which corresponds to the position of haptic interface device **26**. Haptic interface unit **55** further comprises a frame **94** to which magnetically-controllable device **24** and sensor **32** are fixedly mounted, and to which drive mechanism **92** is movably mounted, such as with a low friction element like bearings, bushings, sleeves or the like. The sensor senses rotational displacement of of the steering wheel.

[0072] Drive mechanism **92** comprises a disc **96** fixedly attached to shaft **98**. Disc **96** is configured to engage magnetically-controllable device **24** and sensor **32** during rotation of steering wheel **26**. Disc **96** may comprise a round disc, or only partial segments of a round disc if limited rotation is desired. Disc **96** may comprise peripheral gear teeth as shown or a high-friction surface to engage magnetically-controllable device **24** and sensor **32**.

[0073] Referring to **FIG. 4***a*, the magnetically-controllable device **24** of **FIG. 3** is shown in cross section and comprises a pair of first plate members **38** disposed adjacent to both sides of rotating, disc-like second member **40**. Annular ring member **100**, comprising a high magnetic permeability material, forms a peripheral wall around second member **40** and combines with first member **38** to form a housing **99**. Fastening means **102** may be employed in a plurality of places to hold together the components of the magnetically-controllable device **24**. Fastening means **102** may comprises screws, clamps, bonding or any other method for holding together the components of device **24**. Further holding means may fasten the device **24** to the frame **94**.

[0074] An absorbent element **46** which is preferably a disc shaped ring containing magnetically-controllable medium **34** is sandwiched in two places between first member **38** and second member **40**. Magnetic-field generating device **42**, including coil **48** wound about retainer **50** is disposed adjacent first member **38** and second member **40** at the periphery of magnetically-controllable device **24**. The coil **48** is connected by lead wires **53** to the controller **28** (**FIG. 3**). Thus, a magnetic field represented by flux lines **44** is produced upon the energization of magnetic-field generating device **42**.

[0075] Shaft **104** extends through and is fixedly secured to the second member **40** and interconnects at one end to disc **96** (**FIG. 3**) through engaging member **106**, such as a wheel, gear or pinion. Engaging member **106** is fixedly attached to shaft **104**, such as by a force fit, a set screw, a adhesive or welded bond, a pin, and any other suitable method of holding the engaging member in a fixed relationship to the shaft. Engaging member **106** may have peripheral gear teeth or a high friction surface complementary to the periphery of disc **96**. A first bearing member **108** is disposed on shaft **104** between engaging member **106** and second member **40**. First bearing member **108** allows for the rotation of shaft **104** and supports the shaft against radial loads relative to the first member **38**. A suitable bearing member **108** may comprise a roller bearing, a sleeve or washer of a low friction material such as nylon or Teflon®, or other suitable mechanisms. A second bearing member **110** is disposed at the other end of shaft **104**, on the opposing side of second member **40**. Second bearing member **110** provides radial support for shaft **104** and second member **40**. A suitable bearing member **110** may comprise a thrust bearing, a sleeve or washer of a low friction material such as nylon or Teflon®, and other similar mechanisms.

[0076] Disc **96** and engaging member **106** are sized so that the ratio of their diameters is in a range of ratios that allows magnetically-controllable device **24** to provide a suitable amount of resistance force. Similarly, the ratio of the radius of disc **96** and the radius of engaging member **112** fixedly connected to shaft of sensor **32** (**FIG. 3**) similar to engaging member **106**, must be calibrated to insure proper system performance.

[0077] **FIG. 4***b* illustrates an alternate embodiment of magnetically controllable device **24***b* which may be used in place of the device **24** of **FIG. 4***a*. In this device, the shaft **104***b* is radially supported in a U-shaped first member **38***b* by bearings **108***b*, **110***b*. Engagement member **106***b* engages disc member **96** of **FIG. 3**. The device **24***b* attaches to the frame **94** by fastening means **102***b* received through the ends of first member **38***b* and through spacer **90**. Disc-shaped second member **40** is locked by means of a press fit on shaft **104***b* and rotates therewith. Localized absorbent elements **46***b* are positioned on either side of second member **40***b* and are preferably open celled polyurethane foam adhesively