at least two bearings spaced from each other. The bearings are mounted on the housing in a manner to define a second housing chamber. The control electronics are housed in the second chamber. Typically, the second chamber is adjacent the first chamber.

[0011] For purposes of the description of the preferred embodiments of the invention, the term "working portion" refers to the portion of the rotor which, upon the application of a magnetic field, is engaged by the MR medium to impede movement of the rotor.

[0012] In another aspect of the invention, a controllable MR brake includes a rotor comprising first and second rotor surfaces, an outer periphery, and a working portion on at least one of the first and second rotor surfaces at a position proximate to the outer periphery. The rotor is fixed to a shaft at one shaft end and the rotor and the shaft are rotatable together. A housing includes a first chamber rotatably housing the rotor therein, and including a magnetic field generator spaced from the rotor and configured and positioned for conveying a magnetic flux acting on a volume of controllable material located in the first housing chamber in contact with at least one surface proximate the outer periphery. The controllable material is contained within the first chamber to be in contact with at least the working portion of the rotor. Electronics serve to control and monitor operation of the brake. In a more specific aspect, a second chamber is included in the housing and houses the electronics therein to provide a compact and integrated MR brake with electronics housed therein.

[0013] The magnetic field generator may be an electromagnetic coil, with poles positioned for conveying a flux extending through the field controllable material at least on one side of the rotor, with the rotor configured as a disk. Alternatively, the magnetic field generator can be an electromagnetic coil with poles positioned on both sides of the rotor on the working surfaces thereof for conveying flux extending on both sides, with the rotor also being configured as a disk.

[0014] In specific applications, the shaft for the rotor is supported for rotation by two bearings in the housing, which allow for a second chamber to house electronics, and seals are provided around the shaft at the point of entry into the first chamber for sealing the first chamber to prevent the migration of the controllable material from the first chamber to the second chamber.

[0015] In another more specific aspect of the invention, a return-to-center device such as a torsional spring or like device may be provided to urge the rotor to return to a relative center position.

[0016] Yet still further, the connection between the shaft and the rotor may be arranged so as to allow some backlash between the rotor and the shaft, and the control electronics can be arranged for detecting movement of the shaft and for causing the magnetic field generator to reduce magnetic field in response to the shaft movement to allow easy movement of the control device connected to the brake, such as a steering wheel, back from an end-of-movement position.

[0017] In an alternative configuration, the rotor can be configured to have a working portion on the outer periphery and on the rotor surfaces at a portion proximate the outer periphery. The magnetic field generator which is spaced from the rotor can be configured for conveying a magnetic flux extending through controllable material in directions both, (1) parallel to the shaft and perpendicular to the working portion proximate the outer periphery and (2) perpendicular to the shaft and to the outer periphery of the rotor. This can be done by configuring, for example, the magnetic field generator as an electromagnetic coil with one pole adjacent the working portion on one surface of the rotor, and the other pole extending outside of the outer periphery, and at least co-extensive with the outer periphery of the rotor.

[0018] In yet still a further aspect, the rotor can be configured as having first and second rotor surfaces and an outer periphery. The outer periphery is shaped such that the working portion of the rotor faces radially outward from the rotor and the shaft and has sufficient working surface as to allow a magnetic field to induce sufficient shear stress within the controllable material acting on the working surface to inhibit or prevent motion of the rotor. Such a rotor configuration can include a drum-like configuration in which the outer periphery is shaped fairly wide relative to the actual thickness of the rest of the rotor. In this manner, the magnetic field generator is configured to generate a magnetic field which acts on the controllable material adjacent and in contact with the working portion.

[0019] In such a configuration, the walls of the chamber in which the rotor is housed can be tapered. The taper can be an amount sufficient to enhance migration of field controllable material away from the shaft and toward the working surface of the rotor. In addition, other alternative structures can be built into the rotor proximate the shaft, the housing, and/or on the shaft itself as to create a tortuous path for the field controllable material, making it difficult to have it migrate towards the shaft and in the direction of seals associated with the shaft to retain the material within the chamber housing the rotor. The seals used can be conventional seals and/or of other configurations as will be readily apparent to those of ordinary skill in the art, such as "v-seals" of conventional construction. Similarly, conventional bearings, such as roller elements or bearings, can be used in supporting the shafts as well as other types of bearings which are well known to those of ordinary skill in the art, interchangeable therewith, including, without limitation, dry shaft bearings and the like.

[0020] The foregoing and other aspects will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The accompanying drawings, which form a part of this specification, illustrate several key embodiments of the present invention. The drawings and description together serve to fully explain the invention.

[0022] **FIG. 1** is a longitudinal sectional view of a MR device having side coils mounted therein, and having electronics integrated into the brake.

[0023] **FIG. 2** is a longitudinal sectional view of an MR brake having wrap-around poles for conveying magnetic flux which acts on working surfaces on the periphery of the rotor as well as on a side surface thereof, and also including integrated electronics.