

2 The invention relates to a magnetorheological braking
 3 device having a fixed holder and having at least two brake
 4 components. The magnetorheological braking device in
 5 accordance with the invention may be used in diverse
 6 technical fields for braking relative movements with
 7 respect to one another. The magnetorheological braking
 8 device in accordance with the invention may also be used
 9 as a haptic operating device and for example may be used
 10 in the operation of technical devices in vehicles,
 11 aircraft, airplanes, ships, boats, agricultural technology
 12 (tractors, combine harvesters, harvesting machines, other
 13 field machines for agriculture), construction machines and
 14 machines for material handling (forklift trucks...) or in
 15 medicinal or industrial systems. The invention may also be
 16 used in the operation or as an input device of/for washing
 17 machines, kitchen appliances/household appliances and
 18 devices, radios, cameras and film cameras, hi-fi systems
 19 and television systems, smart devices, smart home
 20 appliances, laptops, PCs, smartwatches, in a crown gear of
 21 wristwatches or as a rotary wheel in a computer mouse or
 22 other appliances.

23 Magnetorheological fluids comprise by way of example
 24 finest ferromagnetic particles such as by way of example
 25 carbonyl iron powder, which are distributed in an oil.
 26 Spherical particles having a diameter dependent upon the
 27 production procedure of 1 to 10 μm are used in
 28 magnetorheological fluids, wherein the particle size and
 29 shape is not uniform. If such a magnetorheological fluid
 30 is influenced using a magnetic field, the carbonyl iron
 31 particles of the magnetorheological fluid concatenate
 32 along the magnetic field lines with the result that the
 33 rheological characteristics of the magnetorheological
 34 fluid (MRF) are considerably influenced in dependence upon
 35 the shape and strength of the magnetic field.

1 WO 2012/034697 A1 discloses a magnetorheological
2 transmission apparatus that comprises two components that
3 may be coupled to one another and it is possible to
4 influence the coupling intensity of said components. A
5 duct is provided with a magnetorheological medium so as to
6 influence the coupling intensity. The magnetorheological
7 medium is influenced in the duct via a magnetic field.
8 Rotary bodies are provided in the duct and regions that
9 are acute-angled and contain the magnetorheological medium
10 are provided on said rotary bodies. The duct or at least a
11 part of said duct may be influenced using the magnetic
12 field of a magnetic field-generating device in order to
13 selectively concatenate the particles and to chock with or
14 to release the rotary body. This magnetorheological
15 transmission apparatus may also be used on a rotary knob
16 for operating technical appliances. Such a
17 magnetorheological transmission apparatus performs and
18 renders possible the transmission of particularly high
19 forces or torques while at the same time being of
20 relatively small construction.

21 WO 2012/034697 A1 also discloses a rotary knob or an
22 operating knob in which the actual knob is attached in a
23 rotatable manner about a shaft. The braking torque may be
24 controlled via the magnetic field of an electrical coil.
25 If a higher braking torque that may be generated is
26 desired, cylindrical rollers may therefore also be used in
27 lieu of spherical rotary bodies with the result that the
28 magnetic field acts upon a longer stretch or larger
29 surface area. It has been shown in particular in the case
30 of rotary knobs or operating knobs having a relatively
31 small diameter that an extension of the roller body does
32 not necessarily lead to an increase of the maximum braking
33 torque that may be generated. It has been proven that the
34 reason for this is that the magnetic field is closed by
35 means of the central shaft or must go through said central
36 shaft. The small diameter of the shaft limits the braking
37 torque that may be generated since the magnetic field that

1 is required for the braking procedure is rapidly saturated
2 in the (shaft) material. The material that the magnetic
3 field flows through no longer permits a higher magnetic
4 flux which is why a more intense magnetic field also
5 cannot arrive at the rollers. The smallest cross-section
6 that the magnetic field flows through in the entire
7 magnetic circuit defines the maximum possible magnetic
8 flux and therefore the maximum braking torque in the
9 braking apparatus. The use of longer rollers as rotary
10 bodies may then even have a disadvantageous effect on the
11 braking torque that may be generated since the magnetic
12 field is distributed over the longer roller surface area.
13 A lesser field strength is applied. Owing to the fact that
14 the braking effect that may be achieved does not depend in
15 a linear manner upon the magnetic field but rather
16 increases disproportionately in the case of more intense
17 magnetic fields, the braking effect that may be achieved
18 accordingly disproportionately decreases in the case of
19 weaker magnetic fields.

20 It is therefore the object of the present invention to
21 provide a magnetorheological braking device, which renders
22 it possible to provide a high braking torque (torque) or a
23 higher braking torque than is the case in the prior art,
24 in particular at small or even up to particularly small
25 diameters.

26 This object is achieved by virtue of a magnetorheological
27 braking device having the features of claim 1. Preferred
28 further developments of the invention are the subject
29 matter of the dependent claims. Further advantages and
30 features of the magnetorheological braking device are
31 apparent in the general description and the description of
32 the exemplary embodiments.

33 A magnetorheological braking device in accordance with the
34 invention comprises a fixed holder and at least two brake
35 components. A first brake component is connected in a

1 rotatably-fixed manner to the holder and extends in an
2 axial direction. The second brake component comprises a
3 sleeve part that is embodied as hollow and that may rotate
4 about the first brake component. A gap is embodied between
5 the first and the second brake component. At least one,
6 two or more in particular rotatable transmission
7 components are arranged in the gap. The gap is filled at
8 least in part with a magnetorheological medium. In this
9 case, the magnetorheological medium lubricates the
10 transmission components. The first brake component
11 comprises a core that extends in the axial direction, said
12 core being embodied from a magnetically conductive
13 material and (at least) one electrical coil that is wound
14 in the axial direction around the core with the result
15 that a magnetic field of the electrical coil extends
16 transversely through the first brake component.

17 The first brake component defines an axial direction.
18 However, the first brake component may also be embodied at
19 least in regions at an angle with respect to the axial
20 direction. The phrase "that the core of the first brake
21 component extends in the axial direction" is understood in
22 the sense of the present invention as that the core also
23 extends at least essentially in the axial direction. The
24 core may comprise an orientation that comprises a slight
25 angle with respect to the axial direction. By way of
26 example, the core may also be oriented at an angle of 2.5°
27 or 5° or 10° or 15° with respect to the axial direction.
28 It is also not necessary for the winding of the electrical
29 coil to likewise be oriented exactly in the axial
30 direction about the core. The electrical coil may also be
31 wound around the core at an angle of 5° or 10° or 15° or
32 the like with respect to the axial direction. However, in
33 all cases it is preferred that an angle between the
34 orientation of the core and the axial direction and an
35 angle of the winding of the electrical coil with respect
36 to the axial direction is less than 20° and in particular
37 less than 10° .

1 The magnetorheological braking device in accordance with
2 the invention has many advantages. One considerable
3 advantage of the magnetorheological braking device in
4 accordance with the invention resides in the fact that the
5 electrical coil is provided on the first brake component.
6 One particular advantage arises by virtue of the fact that
7 the electrical coil is wound about the core at least a
8 significant part of the core, or the entirety of the core,
9 in the axial direction. As a consequence, the magnetic
10 field of the electrical coil extends transverse with
11 respect to the axial direction of the first brake
12 component (in other words radially in relation to the
13 longitudinal axis). This is a considerable difference with
14 respect to the prior art that was disclosed in WO
15 2012/034697 A1, where the electrical coil is provided on
16 the outer component and wherein the windings of the
17 electrical coil extend concentrically around the axial
18 direction. As a consequence, in the prior art a magnetic
19 field is generated, which extends in the axial direction
20 through the interior of the two components. The inner
21 component, usually a thin wall depending upon the
22 construction, in the case of the prior art consequently
23 limits the magnetic flux cross-section and therefore the
24 maximum entire magnetic flux that is to be achieved.
25 Conversely, the magnetic field extends or the magnetic
26 field lines extend in this case transverse with respect
27 thereto and consequently transversely through the first or
28 inner brake component. An extension of the first brake
29 component in this case increases the possible magnetic
30 flux and therefore the braking torque with the same
31 diameter. The possible core diameter that is usually not
32 constructively larger consequently no longer limits the
33 magnetic flux. The winding(s) of the electrical coil in
34 the case of the present invention preferably lie (at least
35 essentially) in one plane or closely adjacent to the
36 plane, which includes the central axis of the axial
37 direction. In contrast, in WO 2012/034697 A1 the central

1 axis lies perpendicular with respect to the plane of the
2 windings of the electrical coil.

3 In the case of the magnetorheological braking device, the
4 transmission components are at least in part surrounded by
5 a magnetorheological medium. Overall, it is preferred that
6 a magnetorheological fluid is used as the
7 magnetorheological medium.

8 It is preferred that multiple in particular rotatable
9 transmission components are arranged distributed over the
10 periphery of the gap. The transmission components may
11 rotate in the gap and rotate relative to one another
12 preferably at least in part during a rotation of the first
13 and second brake component. A central component of the
14 rotatable transmission component or the rotatable
15 transmission component as a whole is in particular
16 dimensionally stable and does not change the outer shape
17 (at least significantly) during a rotation. It is
18 preferred that the rotatable transmission component
19 rotates at least slightly during a rotation of the second
20 brake component relative to the first brake component.

21 In one preferred development, at least one transmission
22 component is embodied as a roller body. The term "roller
23 body" in the sense of the present invention is understood
24 to mean a rotary body that is suitable for rolling in the
25 gap on the first or the second brake component.

26 It is preferred that at least one roller body comprises a
27 cylindrical or spherical or round or rounded (essentially
28 dimensionally stable) cross-section. In particular, a
29 roller body may comprise (an elongated) cylindrical
30 section. The roller body may be rounded on the ends or may
31 be embodied to taper to a point or may be angular. Other
32 sections and in particular end sections are also possible.
33 It is particularly preferred that cylindrical rollers are
34 used as roller bodies. A cylindrical roller body has the

1 considerable advantage that the roller body may be
2 effective over the length of the cylindrical section. As a
3 consequence, the effectiveness increases.

4 One considerable advantage of the present invention
5 resides in the fact that a more intense braking torque may
6 be generated by means of an extension of a by way of
7 example cylindrical roller body. At the same time as the
8 extension of the roller body, the electrical coil may also
9 be extended (in an expedient manner) and said electrical
10 coil extends in the longitudinal direction of the first
11 brake component. A larger penetration surface area (cross-
12 sectional surface area that the magnetic field flows
13 through) is provided for the magnetic field in the case of
14 an electrical coil that is embodied as longer in the axial
15 direction. In the case of the present invention, an
16 extension of the first brake component in the axial
17 direction therefore also enlarges the cross-section of the
18 core. As a consequence, it is possible to achieve a more
19 intense braking torque by means of an extension of the
20 first brake component in the axial direction.

21 In preferred embodiments, at least some of the
22 transmission components are embodied from a magnetically
23 conductive material. In particular, at least some of the
24 transmission components are embodied from a magnetically
25 non-conductive material. If transmission components are
26 used that are embodied from a magnetically conductive
27 material and simultaneously transmission components are
28 also used that are embodied from a magnetically non-
29 conductive material, the magnetic field therefore
30 concentrates itself in the region of the magnetically
31 conductive transmission component. This leads to the
32 concentration of the magnetic field and to in regions an
33 intensification (magnetic field line concentration). Since
34 the relationship between the braking torque that may be
35 generated and the intensity of the magnetic field is not
36 linear and since the braking torque that may be generated

1 becomes disproportionately more intense as the magnetic
2 field becomes more intense, it is possible as a
3 consequence to achieve a considerable intensification of
4 the braking torque that may be generated (in the case of
5 the same installation space/dimensions).

6 In all embodiments, it is not necessary to increase the
7 diameter of the first brake component for an increase of
8 the braking torque that may be generated. This is
9 therefore particularly important because many
10 possibilities for use do not allow a larger outer diameter
11 of a braking device or a larger outer diameter would be a
12 significant competitive disadvantage (for example an
13 excessively large side adjusting wheel in the case of a
14 watch). In order to intensify/increase the braking torque,
15 the first brake component may be embodied as axially
16 longer, which is not a disadvantage or is a small
17 disadvantage in terms of installation space required.

18 In all embodiments, it is preferred that the sleeve part
19 is embodied on a rotary knob. It is preferred that the
20 sleeve part may be formed as a single part with the rotary
21 knob. In the case of such embodiments, it is preferred
22 that the rotary knob or the sleeve part is embodied in the
23 shape of a "pot". The "lid" of the sleeve part may be
24 connected to said sleeve part as a single part or may be
25 fastened separately to said sleeve part.

26 It is preferred that the sleeve part is embodied from a
27 magnetically conductive material and provides an outer
28 ring for the magnetic field. In order to generate a
29 braking torque, the magnetic field penetrates transversely
30 with respect to the axial direction through the first
31 brake component and penetrates the gap at the roller
32 bodies that are embodied as magnetically conductive. The
33 magnetic field exits the roller bodies into the outer ring
34 or into the sleeve part. In the sleeve part, the magnetic
35 field lines extend back to the other side of the first

1 brake component and penetrate (on the opposite side) the
2 gap again at the roller bodies prior to the magnetic field
3 lines again entering into the first brake component. A
4 closed magnetic circuit or closed magnetic field lines
5 is/are consequently provided.

6 A chocking effect forms on the roller bodies under the
7 influence of a magnetic field in the case of a relative
8 rotation of the first and the second brake component
9 relative to one another, as is described in WO 2012/034697
10 A1. The disclosure of this publication is incorporated by
11 reference entirely into this application. The braking
12 torque in the case of the present invention is likewise
13 generated by means of the chocking effect on the
14 transmission component or roller bodies or rotary bodies.

15 It is preferred that at least one radial wall thickness of
16 the sleeve part is at least half as thick as a gap width
17 of the gap and/or a diameter of a transmission component.
18 It is preferred that a radial wall thickness of the sleeve
19 part is greater than 3/4 of the gap width of the gap
20 and/or of a diameter of a transmission component. The
21 radial wall thickness of the sleeve part may also in
22 particular be greater than a diameter of a transmission
23 component. It is possible by means of a sufficient wall
24 thickness of the sleeve part that is embodied from a
25 magnetically conductive material to ensure that the
26 desired field strength of the magnetic field may be
27 generated in the region of the roller body in order to be
28 able to generate a high braking torque.

29 In all embodiments, it is preferred that a length of the
30 first brake component in the axial direction is greater
31 than a length of a transmission component in the axial
32 direction. If the transmission component in the axial
33 direction is embodied as shorter than the first brake
34 component, this leads to a three-dimensional concentration
35 of the magnetic field in the edge region of the

1 transmission component or of the roller body. The magnetic
2 field may practically only penetrate the gap in the
3 sections in which a transmission component or a roller
4 body is located.

5 It is preferred that a length of the gap in the axial
6 direction is at least twice as large as a length of a
7 transmission component in the axial direction. It is also
8 possible and preferred that two or more transmission
9 components and in particular roller bodies are arranged in
10 the axial direction one behind the other. In this case, it
11 is possible for example that magnetically conductive
12 transmission components and magnetically non-conductive
13 transmission components alternate in the axial direction
14 with the result that by way of example each second or
15 third transmission component in the axial direction is
16 embodied in a magnetically non-conductive manner. As a
17 consequence, a concentration of the magnetic field is
18 produced that is advantageous for the maximum braking
19 torque that may be generated.

20 It is preferred that the first brake component is embodied
21 in an essentially cylindrical manner and comprises a
22 cylindrical base body as a core and the electrical coil or
23 the electrical coils. It is also possible that by way of
24 example a sphere for mounting the rotary knob is included
25 and said sphere may be arranged centrally on the distal
26 end in order to provide a simple bearing arrangement
27 between the first brake component and the second brake
28 component.

29 It is preferred that the electrical coil is wound in axial
30 grooves and transverse grooves of the cylindrical base
31 body (of the first brake component). It is preferred that
32 the axial grooves and the transverse grooves are filled at
33 least in part with casting compound. As a consequence,
34 magnetorheological medium or magnetorheological fluid is
35 prevented from penetrating into the region of the coil

1 wires. This could otherwise lead to a separation of the
2 fluid.

3 In preferred embodiments, it is possible that the
4 cylindrical base body (of the first brake component) is
5 surrounded by a sleeve body that is fixedly connected to
6 the cylindrical base body. In this case, a radial
7 thickness of the sleeve body is preferably considerably
8 smaller than half of the radial gap width of the gap. It
9 is particularly preferred that the radial thickness of the
10 sleeve body is smaller than 1/4 of the radial gap width of
11 the gap. It is particularly preferred that a radial
12 thickness of the sleeve body is less than 1/6, 1/8 or 1/10
13 of a diameter of a roller body. In particularly preferred
14 embodiments, the sleeve body is embodied from a
15 magnetically conductive material. The sleeve body provides
16 a protective sleeve. As a consequence, an abrasion of the
17 casting compound as the rotary body is rotating is
18 reliably prevented. Fundamentally namely no or only an
19 extremely small amount of magnetic field penetrates the
20 gap in the region of the casting compound with the result
21 that in the region of the casting compound no significant
22 forces act upon the roller body and consequently the
23 casting compound. Nevertheless, in the case of continuous
24 operation, a wear may occur that is reliably avoided by
25 means of a thin sleeve body. A thin sleeve body reduces
26 the magnetic loss since only a small part of the magnetic
27 field is short circuited via the sleeve body.

28 It is preferred that the holder comprises a cable bushing.
29 Connecting cables for the coil and/or sensor cable and the
30 like may be further guided by means of the holder or by
31 means of the cable bushing of the holder. As a
32 consequence, a simple assembly procedure and cost-
33 effective production are rendered possible.

34 It is preferred that the holder comprises a receiving
35 arrangement for the rotatably-fixed connection to the

1 first brake component. In this case, the holder may
2 receive the first brake component in a non-positive-
3 locking manner and/or positive-locking manner. During
4 operation, the braking torque between the first brake
5 component and the second brake component is transmitted
6 via the holder.

7 It is preferred that the holder comprises a cylindrical
8 running surface for a bearing arrangement and supports the
9 sleeve part in a rotatable manner on the holder.

10 It is preferred that a seal is arranged on the cylindrical
11 running surface, wherein the seal is arranged in
12 particular closer to the gap than the bearing arrangement.
13 As a consequence, the bearing arrangement is reliably
14 protected from the magnetorheological medium. Such an
15 embodiment renders possible a compact construction and a
16 reliable operation. The bearing arrangement may be for
17 example a slide bearing or a roller bearing.

18 It is preferred that the cylindrical running surface is
19 hardened and/or comprises a higher surface quality than
20 the radial outer surface of the receiving arrangement. As
21 a consequence, it is possible to reduce production costs.

22 In advantageous embodiments, the cylindrical running
23 surface comprises an outer diameter that is at least 3 mm
24 smaller than an outer diameter of the receiving
25 arrangement of the holder.

26 In preferred embodiments, the first brake component
27 comprises a feed-through for a shaft that is connected in
28 a rotatably-fixed manner to the second brake component. In
29 particular, the feed-through is embodied centrally on the
30 first brake component. Such an embodiment renders it
31 possible for example to attach a part of an angle sensor
32 (for example a rotary encoder) to the shaft. This part of
33 the angle sensor is then received in a manner in which it

1 is protected against the outer environment. The angle
2 sensor may still be arranged by way of example within the
3 magnetorheological braking device for example within the
4 holder. It is also possible that the shaft extends into
5 the console on which the magnetorheological braking device
6 is fastened. It is then possible for a part of an angle
7 sensor to be received within the console in a protected
8 manner.

9 It is preferred that the holder is fastened to a console.
10 A further part of an angle sensor is preferably fastened
11 to the holder or the console. By way of example, a
12 magnetic encoder may be fastened to the shaft and a
13 detector may be fastened to the holder or the console with
14 the result that corresponding rotary signals may be
15 detected in the case of a rotational movement of the
16 shaft. In this case, it is possible to detect a relative
17 positioning arrangement or also an absolute positioning
18 arrangement. It is preferred that the rotary encoder
19 generates more than 10 000 pulses (increments) per
20 rotation, particularly preferably more than 30 000 pulses
21 (increments) per rotation.

22 It is preferred that a user interface, an operator panel,
23 a display, a touch-sensitive display with or without
24 haptic feedback and/or at least one sensor is attached to
25 the axial end that lies opposite the holder. Such an
26 embodiment renders it possible in addition to the
27 operation to also simultaneously display or output
28 information during the operation. By way of example, an
29 operating knob having a simultaneous output display is
30 rendered possible.

31 In all embodiments, it is possible that a pressure
32 sensitive sensor is attached to the holder or such a
33 sensor is allocated to the holder. By way of example, a
34 pressure-sensitive sensor may be attached in the holder.
35 It is however also possible that a piezo sensor is

1 attached to the lower part etc. The holder may also be
2 embodied in a two-part manner and may register an axial
3 displacement of the two parts relative to one another. In
4 this case, a haptic feedback may be provided.

5 In all embodiments, it is preferred that a difference
6 between an inner diameter of the sleeve part and an outer
7 diameter of the first brake component is greater than 3 mm
8 and less than 50 mm. It is likewise preferred that an
9 outer diameter of the sleeve part is between 15 mm or 20
10 mm and 90 mm. It is preferred that a height of the sleeve
11 part is between 10 mm and 60 mm. In all embodiments, it is
12 preferred that a control device is included, which is
13 embodied to provide a variable braking effect using the
14 electrical coil.

15 Overall, the present invention operates in a particularly
16 preferred manner according to the basic principle of
17 providing a chocking arrangement, wherein a transmission
18 component and in particular a roller body or a rotary body
19 rolls on said transmission component at a specific
20 distance with respect to the walls. The chocking effect is
21 provided by means of a magnetic field with the result that
22 a high braking torque may be generated. In contrast to the
23 previous prior art, where a coil that is wound radially
24 around the axis of a brake component generates a magnetic
25 field in the axial direction of the brake component, in
26 accordance with the present invention a magnetic field is
27 generated transverse to (the core) of the first brake
28 component. It is possible to achieve an improved
29 scalability by means of using this axial coil. As a
30 consequence, it is possible by means of longer roller
31 bodies and an axially longer electrical coil to generate a
32 scalable and greater braking torque. In this case it is
33 not necessary for the diameter of the first brake
34 component to be selected as larger in order to conduct a
35 corresponding magnetic field since the surface area of the
36 core (cross-sectional surface area) enlarges with an axial

1 extension of the core. Where applicable, the axial length
2 may also be reduced if only a relatively small braking
3 torque is required. The installation space may be adapted
4 accordingly.

5 A further advantage is that the leading-out of the
6 electrical connecting cable for the electrical coil is
7 possible in a simple manner even for large-scale
8 production. Sealing of the magnetorheological braking
9 device and scaling can be made possible by simple means.

10 Fundamentally, it is possible for the magnetorheological
11 braking device to generate a greater torque over longer
12 roller bodies since the operative length increases.
13 Simultaneously, it is ensured by means of the larger core
14 surface that the roller bodies are always exposed to a
15 corresponding magnetic flux density. The magnetic field
16 strength when "chocking" on the roller bodies may be
17 selected as higher than in the prior art. Long roller
18 bodies may be used which a sufficiently intense magnetic
19 field may be guided to.

20 In particular, the magnetic field that is generated by the
21 electrical coil passes radially through the core then
22 through the roller bodies and closes itself via the sleeve
23 part or the outer cylinder. In this case, the magnetic
24 field lines connect once in the one, and for example,
25 lower half and once in the other, and for example, upper
26 half of the sleeve part. In simple embodiments, the
27 magnetic flux consequently runs in an essentially two-
28 dimensional manner. In this case, it does not matter how
29 long or how tall the roller bodies are embodied. As a
30 consequence, it is possible to achieve an arbitrary
31 scaling in the length since the magnetic field
32 transmitting surface area enlarges accordingly. In the
33 case of electrical coils that are wound concentrically
34 around the longitudinal direction of the first brake
35 component (prior art), the cross-sectional surface area in

1 the core conversely always remains the same and in this
2 respect forms a bottleneck for the magnetic field as long
3 as the diameter is not changed. A larger diameter of the
4 first brake component however also changes the
5 requirements for installation space, the installation
6 dimensions and the weight of the magnetorheological
7 braking device. Moreover, the torque intervals and the
8 rotational speeds of the roller bodies change, which is
9 not always advantageous. In the case of a linear extension
10 as is the case in the present invention, this conversely
11 does not change.

12 If longer roller bodies are used, the braking effect of a
13 long roller may be better than in the case of two short
14 rollers that comprise the same overall length. This is due
15 *inter alia* to the fact that more of the fluid in terms of
16 distance must be displaced since the edge is further away
17 (hydrodynamic pressure).

18 In preferred embodiments, the magnetorheological braking
19 device comprises a diameter of the sleeve part of between
20 approximately 10 and 40 mm (+/- 20 %) in preferred
21 embodiments approximately 25 mm.

22 In all embodiments, it is possible that the electrical
23 coil is embodied as longer in the axial direction than the
24 roller bodies. As a consequence, a concentration of the
25 magnetic field on the roller bodies is achieved.

26 Overall, the invention provides an advantageous
27 magnetorheological braking device ("MRF brake"). In this
28 case, the outer diameter of the MRF brake is usually
29 predetermined particularly in the case of haptic
30 applications. In this case, there are ergonomic
31 guidelines. It is therefore generally not easily possible
32 to enlarge the core cross-section because the outer
33 diameter therefore also increases (knob outer diameter;
34 surface area for fingers). Moreover, more braking torque

1 is required with an increasing outer diameter since the
2 torque intervals therefore enlarge (the finger force, in
3 other words the (tangential) force between the actuating
4 finger(s) and the brake element or the outer surface area
5 of the brake element must or should remain identical since
6 on the one hand only a specific force may be applied by
7 the user and the necessary forces are important at the
8 fingers (fingertips) for physical comfort during the
9 actuating procedure (operating quality).

10 The electrical coil in the case of the solution in
11 accordance with the invention extends axially (in contrast
12 to the prior art). The magnetic field that is generated by
13 the coil passes radially through the core, then through
14 the roller body and closes itself via the outer cylinder
15 (respectively through the opposing halves). This always
16 remains the same regardless of how tall (or long) the
17 roller bodies or MRF brake is.

18 It is advantageous that the MRF brake or the haptic knob
19 may be scaled arbitrarily in length since the magnetic
20 field transmitting surface enlarges accordingly. In the
21 case of radial electrical coils, the cross-sectional
22 surface area in the core always remains the same and may
23 form a bottleneck for the magnetic field as long as the
24 diameter is not changed. If the diameter is changed, many
25 aspects change accordingly (torque intervals, rotational
26 speeds of the rollers...), which is not always advantageous.
27 In the case of a linear extension of the MRF brake in
28 accordance with the invention, this does not change.

29 The invention achieves the aim of obtaining an MRF brake
30 that is as simple as possible however nevertheless
31 effectively scalable, said MRF brake having a high braking
32 torque while having a compact outer diameter.

33 The axial electrical coil that is wound and cast (in the
34 axial direction) around the core generates a magnetic

1 field. This magnetic field closes itself via the roller
2 bodies and the sleeve part that forms an outer cylinder as
3 described above. It is advantageous to cast the electrical
4 coil so that the MR fluid (carrier fluid) does not reach
5 into the empty spaces between the coil wires (capillary
6 effect). Otherwise this may lead to separation occurring.
7 In lieu of a (cylindrical) coil wire, it is also possible
8 to use a flat material of copper or another suitable
9 material.

10 The core, the roller bodies and the outer cylinder may be
11 produced from a simple steel (for example S235) without
12 high demands on the surface quality and hardness, said
13 simple steel preferably having good magnetic properties.
14 However, it is also possible to use (multiple stacked one
15 above the other) roller bodies or spheres or transmission
16 components of some other shape. Spacers (guide plates) may
17 be provided between the roller bodies.

18 It is not absolutely necessary for the space (gap) between
19 the core and outer cylinder to be (almost) completely
20 filled with roller bodies. Spacers that are embodied from
21 a magnetically non-conductive material - together with
22 roller bodies that are embodied from a magnetically
23 conductive material - may also be used between the roller
24 bodies or one or multiple roller bodies.

25 The core together with the electrical coil and casting
26 compound are preferably centered and fixed in a "holder"
27 (non-positive-locking or positive-locking connection) and
28 the counter torque is transmitted via this holder to the
29 console (base plate; receiving plate; housing). The holder
30 preferably has a hole through which the cables are guided.
31 It is preferred that a sealing element (for example an O-
32 ring) seals the cable with respect to the holder or the
33 interior with the result that fluid cannot escape from the
34 interior outwards via the cable. In addition to the
35 (coils) cable, it is also possible for a temperature

1 sensor cable or another sensor cable to be guided through
2 this opening. The cylindrical surface of the tapered
3 holder is preferably provided in such a manner that said
4 surface has running surface characteristics (coated or
5 hardened or similarly annealed with a higher surface
6 hardness and low surface roughness).

7 The holder may also be produced from a material different
8 to that of the core, roller body or outer cylinder. The
9 diameter reduction of the holder on the running surface
10 has the advantage that the frictional radius for the
11 sealing element is reduced which reduces the entire
12 friction. Moreover, a bearing element may be used owing to
13 the increased installation height as a result, said
14 bearing element comprising the same bearing outer diameter
15 as the inner diameter of the sleeve part. This reduces the
16 production costs of the sleeve part, since it is not
17 necessary to provide a recess during the production
18 process. The preferred roller body height is between 3 and
19 6 mm, however it may also be 1 or 2 mm. In this field, it
20 is difficult to obtain good bearing or sealing elements if
21 the inner diameter of the holder does not provide
22 additional installation height.

23 It is possible to attach a decorative or other
24 transmission element above the outer cylinder, for example
25 a rubberized knob.

26 When viewed axially from above, a sphere or a spherical or
27 a spherically similar component (may also be a hemisphere)
28 is preferably between the outer cylinder and the casting
29 compound. This guides the two parts relative to one
30 another.

31 It is preferred that the sphere is fixed in the casting
32 compound and the inner axial end face of the outer
33 cylinder rotates relative to said sphere. A simple, low
34 friction and cost effective bearing arrangement (bearing

1 position) is therefore provided. A conical shape or the
2 like is also possible. In lieu of this type of bearing
3 arrangement, it is also possible however to select any
4 other type of bearing arrangement (for example a slide
5 bearing or roller bearing).

6 There is a space between the roller lower part and the
7 seal. This space is used in particular as a reservoir and
8 also as a temperature compensating space. A temperature
9 compensating element (for example an O-ring filled with
10 air) may also be accommodated in this space. A closable
11 filling opening or venting opening may likewise be
12 provided in this region in the sleeve part (or the outer
13 cylinder).

14 It is preferred that at least one component, which the
15 magnetic field flows through, is embodied at least in part
16 or entirely from the material FeSi₃P.

17 It is preferred that at least one microphone and or a
18 sound recognition device and/or a voice recognition device
19 is included or allocated. A computer device may also be
20 included. Sounds and/or voice commands may be evaluated
21 locally and/or remotely. By way of example, a computer
22 unit (processor) may be provided locally. The processing
23 may also be performed in a remote network and only the
24 result - in other words the command that is to be
25 performed - may be returned.

26 The invention also relates to a method for operating
27 appliances using an (adaptive) braking device having a
28 rotatable brake component for manual rotation. In this
29 case, the braking device is controlled in dependence upon
30 the manual rotation of the rotatable brake component and
31 at least also by means of at least one command that is
32 identified by means of sound recognition.

1 It is preferred that various voice commands and/or sound
2 signals and/or clapping signals may be identified and
3 differentiated using the sound recognition. The number of
4 different and differentiable commands may be limited,
5 however it is not essential that they are limited.

6 It is possible and preferred that sounds are received and
7 are processed locally and/or remotely.

8 At least one magnetorheological braking device is
9 preferably controlled as described above.

10 A voice-controlled input may be used for the control
11 procedure. It is possible and preferred in all cases that
12 an adaptive braking device or adaptive haptic operating
13 device is used with a braking device. The adaptivity may
14 depend upon the operating mode that is selected by sound
15 or for example voice command.

16 Further advantages and features of the present invention
17 are apparent in the exemplary embodiments, which are
18 explained below with reference to the attached figures.

19 In the figures:

20 Figure 1 illustrates a simplified schematic three-
21 dimensional view of a magnetorheological braking
22 device in accordance with the invention;

23 Figure 2 illustrates a simplified schematic cross section
24 through a roller body of a magnetorheological
25 braking device;

26 Figure 3 illustrates a schematic cross section through a
27 magnetorheological braking device in accordance
28 with the invention;

1 Figure 4 illustrates a cross section rotated by 90° of
2 the magnetorheological braking device according
3 to fig. 3;

4 Figure 5 illustrates a plan view of the
5 magnetorheological braking device according to
6 figure 3 and 4;

7 Figure 6 illustrates the section B-B in figure 5;

8 Figure 7 illustrates a horizontal section C-C through the
9 magnetorheological braking device at a mean
10 height;

11 Figure 8 illustrates a horizontal section D-D similar to
12 figure 7 having marked magnetic field lines;

13 Figure 9 illustrates the section A-A according to figure
14 5;

15 Figure 10 illustrates a vertical section through a further
16 exemplary embodiment of a magnetorheological
17 braking device in accordance with the invention;
18 and

19 Figures 11A-11C illustrate possible torque curves over the
20 angle of rotation of a magnetorheological
21 braking device in accordance with the invention.

22 Figure 1 illustrates a schematic perspective view of a
23 magnetorheological braking device 1 that is embodied in
24 this case as a haptic operating knob 100 and is fastened
25 to a console 50 or comprises such a console 50. The
26 magnetorheological braking device 1 comprises a sleeve
27 part 13 that is received in a rotatable manner. It is
28 possible to adjust the torque that is required in order to
29 rotate the sleeve part 13.

1 A user interface 43 is arranged on the upper side of the
2 magnetorheological braking device 1. Such a user interface
3 43 may be embodied by way of example as a display device
4 or also as a touch sensitive input possibility (touchpad,
5 movement control and gesture control, image recognition...).

6 The haptic operating knob 100 may be used by way of
7 example so as to operate machines, medical appliances or
8 for use in and for the motor vehicle. It is also possible
9 to use said haptic operating knob on other appliances or
10 other apparatuses.

11 Figure 2 illustrates a simplified schematic cross-
12 sectional view of a magnetorheological braking device 1 in
13 accordance with the invention for influencing the
14 transmission of force between two brake components 2 and
15 3. In this case, a roller body or rotary body 11 is
16 provided between the two brake components 2 and 3 in fig.
17 2. The roller body 11 is embodied in this case as a sphere
18 14. However, it is likewise possible to embody the roller
19 bodies 11 as cylinders or ellipsoids, rollers or other
20 rotatable rotary bodies. It is also possible to use as
21 roller bodies rotary bodies that are not rotationally
22 symmetrical in the proper sense of the word such as by way
23 of example a gear wheel or rotary body 11 having a
24 specific surface structure. The roller bodies 11 are not
25 used for the bearing arrangement with respect to one
26 another but rather for transmitting torque.

27 A duct 5 is provided between the brake components 2 and 3,
28 said duct in this case being filled with a medium 6. The
29 medium in this case is a magnetorheological fluid, which
30 comprises by way of example an oil as a carrier fluid in
31 which ferromagnetic particles 19 are provided. Glycol,
32 fat, water and viscous materials may also be used as a
33 carrier medium without being limited to any material. The
34 carrier medium may also be gaseous or the carrier medium
35 may be omitted (vacuum). In this case, only particles that

1 may be influenced by means of the magnetic field may be
2 filled in the duct.

3 The ferromagnetic particles 19 are preferably carbonyl
4 iron powder, wherein the size distribution of the
5 particles depends upon the specific application case.
6 Specifically, a distribution of the particle size between
7 one and ten micrometers is preferred, wherein however
8 larger particles of twenty, thirty, forty and fifty
9 micrometers are also possible. Depending upon the
10 application case, the particle size may also be clearly
11 larger and even advance into the millimeter range
12 (particle spheres). The particles may also comprise a
13 specific coating/jacket (titanium coating, ceramic jacket,
14 carbon jacket etc.) so that said particles may better
15 withstand the high-pressure loads that occur depending
16 upon the application case. The magnetorheological
17 particles may be produced not only from carbonyl iron
18 powder (pure iron) for this application case but rather
19 for example may also be produced from special iron (harder
20 steel).

21 The roller body 11 is preferably set into rotation about
22 its rotary axis 12 by means of the relative movement 17 of
23 the two brake components 2 and 3 and runs practically on
24 the surface of the brake component 3. The roller body 11
25 simultaneously runs on the surface of the other brake
26 component 2 with the result that a relative speed 18 is
27 provided at that location.

28 In fact, the roller body 11 does not have direct contact
29 with the surface of the brake components 2 and/or 3 and
30 therefore does not roll directly on said brake component.
31 The free gap 9 from the roller body 11 to one of the
32 surfaces of the brake components 2 or 3 is for example 140
33 μm . In one specific embodiment having particle sizes
34 between 1 μm and 10 μm , the free gap is in particular

1 between 75 μm and 300 μm and particularly preferably
2 between 100 μm and 200 μm .

3 The free gap 9 is in particular at least ten times the
4 diameter of a typical average particle diameter. The free
5 gap 9 is preferably at least ten times a largest typical
6 particle. As a result of the lack of direct contact, there
7 is a particularly low level of basic friction/force/torque
8 during the relative movements of the brake components 2
9 and 3 with respect to one another.

10 If the magnetorheological braking device 1 is influenced
11 using a magnetic field, the field lines form in dependence
12 upon the distance between the roller bodies 11 and the
13 brake components 2, 3. The roller body 11 is embodied from
14 a ferromagnetic material and for example in this case from
15 ST 37 (S2305). The steel type ST 37 has a magnetic
16 permeability μ_r of approximately 2000. The field lines
17 (magnetic circuit) pass through the roller body and
18 concentrate themselves in the roller body. A high magnetic
19 flux density prevails on the roller body on the in this
20 case radial entering surface area and exiting surface area
21 of the field lines in the duct 5. The inhomogeneous and
22 strong field in said duct leads to a local and intense
23 linkage of the magnetic polarizable particles 19 (magnetic
24 concatenation). The effect is intensely increased by means
25 of the rotational movement of the roller body 11 in the
26 direction of the chock that forms in the
27 magnetorheological fluid and the possible braking torque
28 or coupling torque is extremely increased far beyond the
29 amount that may normally be generated in the
30 magnetorheological fluid. It is preferred that the roller
31 body 11 and brake components 2, 3 are embodied at least in
32 part from ferromagnetic material, which is why the
33 magnetic flux density is higher the smaller the distance
34 between the rotary body 11 and brake components 2, 3. As a
35 consequence, an essentially chock shaped region 16 forms
36 in the medium in which the gradient of the magnetic field

1 increases intensely toward the acute angle at the contact
2 site or the region of the smallest gap.

3 Despite the gap between the roller body 11 and the brake
4 components 2, 3, it is possible by means of the relative
5 speed of the surfaces with respect to one another to set
6 the roller bodies 11 into a rotational motion. The
7 rotational motion is possible without and also with an
8 active magnetic field 8.

9 If the magnetorheological braking device 1 is exposed to a
10 magnetic field 8 of an electrical coil 26 that is not
11 illustrated in this case in figure 2, the individual
12 particles 19 of the magnetorheological fluid 6 concatenate
13 along the field lines of the magnetic field 8. It is to be
14 noted that the vectors that are marked in figure 2 only
15 approximately schematically represent the region of the
16 field lines that is relevant for influencing the MRF. The
17 field lines enter essentially perpendicular on the
18 surfaces of the ferromagnetic components into the duct 5
19 and must in particular not extend in a straight line in
20 the acute-angled range 10.

21 Simultaneously, some material is set in rotation on the
22 periphery of the roller body 11 by the magnetorheological
23 fluid with the result that an acute-angled region 10 forms
24 between the brake component 3 and the roller body 11. An
25 identical acute-angled region 10 forms on the other side
26 between the roller body 11 and the brake component 2. The
27 acute-angled regions 10 may comprise by way of example a
28 chock shape 16 in the case of roller bodies 11 that are
29 embodied in a cylindrical manner. The further rotation of
30 the roller body 11 is prevented as a result of the chock
31 shape 16 with the result that the effect of the magnetic
32 field on the magnetorheological fluid is intensified since
33 the medium 6 is held together more intensely in the acute-
34 angled region 10 by means of the magnetic field that is
35 acting within said acute-angled region. As a consequence,

1 the effect of the magnetorheological fluid intensifies in
2 the accumulated cluster (the concatenation in the fluid
3 and therefore the cohesion or the viscosity), which
4 impedes the further rotation or movement of the rotary
5 body 11.

6 It is possible by means of the chock shape 16 to transmit
7 significantly greater forces or torques than would be
8 possible with a comparable construction that only uses the
9 shearing motion without the chocking effect.

10 The forces that may be transmitted directly by means of
11 the magnetic field that is applied only represent a small
12 part of the forces that may be transmitted by means of the
13 apparatus. It is possible by means of the magnetic field
14 to control the formation of the chock and consequently the
15 mechanical force reinforcement. The mechanical
16 reinforcement of the magnetorheological effect may go so
17 far as that a transmission of force may also be possible
18 after disconnecting an applied magnetic field if the
19 particles have been chocked.

20 It has been proved that a considerably greater effect of a
21 magnetic field 8 of a specific intensity is achieved by
22 means of the chocking effect of the acute-angled regions
23 10. In this case, it is possible to intensify the effect
24 many times over. In one specific case, an approximately
25 ten times as strong an influence of the relative speed of
26 two brake components 2 and 3 with respect to one another
27 than in the case of the prior art is observed in the case
28 of MRF couplings according to the shear principle in which
29 a magnetorheological fluid is arranged between two surface
30 areas that are moving with respect to one another and said
31 magnetorheological fluid is exposed to the shearing forces
32 of the surface areas that are moving with respect to one
33 another. The possible reinforcement in this case by means
34 of the chocking effect depends upon different factors.
35 Where applicable, said reinforcement may be further

1 intensified by means of a greater surface roughness of the
2 roller bodies 11. It is also possible that outwardly
3 protruding projections are provided on the outer surface
4 of the roller bodies 11 and said projections may lead to
5 an even stronger chock formation.

6 The chocking effect is distributed in a planar manner on
7 the roller body 11 and the components 2 or 3.

8 Figure 3 illustrates a vertical section through a
9 magnetorheological braking device 1 that comprises two
10 brake components 2 and 3. The first brake component 2 is
11 arranged in this case in the interior of the second brake
12 component 3 and is held in a positive-locking and/or non-
13 positive-locking manner by means of a holder 4. The holder
14 4 may be fastened by way of example on an external
15 console. The holder 4 is regularly fastened in a
16 rotatably-fixed manner. The second brake component 3 is
17 received on the first brake component 2 and may rotate
18 relative to said first brake component.

19 The second brake component 3 is embodied as star-shaped
20 and comprises the sleeve part 13 and a cover that closes
21 the top of the sleeve part 13. The second brake component
22 3 is therefore only accessible from the in this case lower
23 end through which the first brake component 2 is guided
24 using the holder 4. A cylindrical running surface 37 is
25 embodied on the holder 4 in the region of the lower end of
26 the first brake component 2. A hardened surface or a
27 surface with corresponding qualities is provided in said
28 region. A bearing arrangement 30 for the rotatable bearing
29 arrangement of the second brake component 3 is attached to
30 this cylindrical running surface 37. A seal 38 is provided
31 in the axial direction 20 further inwards adjacent to the
32 bearing arrangement 30. The seal 38 reliably seals the
33 interior. By virtue of the fact that only one seal 38 is
34 provided on the outside, a low basic torque is required in

1 order to rotate the second brake component 3 in the case
2 of a disconnected magnetic field.

3 The first brake component 2 comprises a cylindrical base
4 body 33 that comprises axial grooves 31 and transverse
5 grooves 32 (cf. figure 7 and figure 4) the windings of the
6 electrical coil 26 are wound into the axial grooves 31 and
7 transverse grooves 32 with the result that the individual
8 windings of the electrical coil 26 do not protrude
9 outwards from the cylindrical base body 33. In this case
10 in the exemplary embodiment, the axial grooves 31 and the
11 transverse grooves 32 are subsequently backfilled by means
12 of a casting compound with the result that overall a
13 cylindrical body of the first brake component 2 is
14 provided.

15 A sphere 22 (or hemi-sphere) is arranged or in part molded
16 centrally on the upper end of the first brake component 2
17 in order to provide a second bearing arrangement between
18 the first brake component 2 and the second brake
19 components 3 in a simple manner.

20 A gap 5 is embodied radially between the outer wall of the
21 first brake component 2 and the inner wall of the sleeve
22 part 13, said gap being embodied in this case essentially
23 as a hollow cylindrical gap. Multiple transmission
24 components 11 are arranged in the gap, said transmission
25 components in this case being embodied as roller bodies.
26 The roller bodies 11 are embodied in this case as
27 cylindrical roller bodies and comprise an outer diameter
28 that is slightly smaller than the gap width of the gap 5.
29 The gap 5 is furthermore in this case filled with a
30 magnetorheological medium. It is possible to arrange by
31 way of example an O-ring or the like that is filled with
32 air or another gas in the lower region of the gap, said O-
33 ring providing a volume compensation in the event of
34 temperature fluctuations. Moreover, as a consequence a
35 reservoir is formed in the lower region of the gap for use

1 in case during operation magnetorheological fluid or
2 medium escapes from the interior to the outside.

3 The (usable) gap length 5b of the gap 5 is greater here
4 than the length 11b of the roller bodies 11. The
5 electrical coil in this case is also embodied as longer in
6 the axial direction 20 than the length 11b of the roller
7 bodies 11.

8 The core 21 is apparent in the interior of the electrical
9 coil 26. The holder 4 comprises a radially enlarged
10 receiving arrangement 36 for receiving the first brake
11 component 2 in a rotatably-fixed manner. Through the
12 holder 4, a cable feed-through extends downwards through
13 the holder 4. Cables 45 are guided at this location so as
14 to connect to the electrical coil 26 and where applicable
15 sensor lines. A control device 27 may be provided in the
16 base of the holder 4 or at other suitable positions in
17 order to provide control as required.

18 Figure 4 illustrates a section offset by 90° through the
19 magnetorheological braking device 1 in accordance with
20 figure 3, wherein in this case the transverse grooves 32
21 are apparent in which the electrical coil 26 is wound.
22 Casting compound 28 is provided in the axial direction on
23 both ends respectively. A separate seal is provided in the
24 region of the cable feed-through 35 via by way of example
25 the marked O-ring or the like.

26 It is also possible that individual roller bodies of the
27 roller bodies that are arranged distributed over the
28 periphery may be embodied as magnetically non-conductive
29 transmission components 11c. However, it is also possible
30 that all the roller bodies are embodied from a
31 magnetically conductive material. If individual roller
32 bodies are embodied from a magnetically non-conductive
33 material, this therefore leads to a concentration of the
34 magnetic field on the magnetically conductive roller

1 bodies, as a result of which it is possible to generate a
2 stronger braking torque.

3 A length or height 13c of the sleeve part 13 or the second
4 brake component 3 in the axial direction 20 is preferably
5 between 10 mm and 60 mm. A cover 49 may be attached on the
6 outside to the second brake component 3 with the result
7 that the outer appearance of the rotary knob 23 is
8 essentially determined by means of the surface of the
9 cover 49.

10 The material of the sleeve part 13 is magnetically
11 conductive and is used so as to close the magnetic
12 circuit. A wall thickness 13d of the sleeve part 13 is
13 preferably at least half as large as a diameter 11a of the
14 roller bodies 11.

15 The diameter 36a of the receiving arrangement 36 is
16 preferably considerably larger than the diameter 37a of
17 the cylindrical running surface 37. As a consequence, the
18 friction on the seal 38 is reduced. Moreover, it is
19 possible to use standardized bearings.

20 It is also possible to embody the core 21 as two parts.
21 The division preferably extends along the center line that
22 is marked in figure 4, as a result of which a left-hand
23 side and a right-hand side (core) half is provided. The
24 two core halves may be spaced from one another by means of
25 a magnetically non-conductive element (for example seal).
26 It is preferred that the casting compound volume 28 is
27 then a part of the core half (halves) as a result of which
28 a semicircular element having a circumferential groove is
29 provided on the dividing surface for the electrical coil.
30 Further preferably, the receiving arrangement 36 is also
31 divided into two halves. One receiving half may also form
32 one part with a core half (may be embodied as a single
33 part) or a core half may be embodied with a complete
34 receiving unit 36 as a single part.

1 Figure 5 illustrates a plan view of the magnetorheological
2 braking device 1, wherein the roller bodies 11 are
3 apparent. The cylindrical base body having the electrical
4 coil 26 is apparent in the central region.

5 Figure 6 illustrates the section B - B in accordance with
6 figure 5. The roller bodies 11 are arranged in the gap 5,
7 said roller bodies in this case comprising a (relatively
8 short) length 11b that is considerably shorter than the
9 gap length 5b. As illustrated in the lower part of figure
10 6, multiple roller bodies may be provided axially one
11 behind the other and some of said roller bodies are also
12 magnetically non-conductive, as the roller body 11c marked
13 with the dotted line illustrates. The core 21 is apparent
14 in the central region, said core being surrounded by the
15 coil 26.

16 Figure 7 illustrates a horizontal section at a mean height
17 of the magnetorheological braking device 1, wherein the
18 axial grooves 31 are apparent in which the windings of the
19 electrical coil 26 are wound. The groove is filled with
20 casting compound 28 in order to seal and to close said
21 groove with the result that overall a cylindrical
22 embodiment of the first brake component 2 is provided.

23 Figure 8 illustrates in principle the same illustration as
24 figure 7 except the hatching has been removed for improved
25 clarity and for this purpose magnetic field lines of the
26 magnetic field 8 are marked. The magnetic field extends
27 transversely with respect to the longitudinal direction
28 through the core 21 and enters in this case approximately
29 horizontally at the two ends out of the core 21 through
30 the roller bodies 11 and then enters into the sleeve part
31 13. The magnetic field lines close themselves as
32 illustrated in figure 8. In this case, multiple roller
33 bodies are exposed to a magnetic field with the result
34 that the chocking effect occurs respectively at multiple -
35 however not all - roller bodies. The roller bodies in the

1 region of the casting compound are essentially free from
2 the magnetic field.

3 Figure 9 illustrates the cross-section A - A in figure 5,
4 wherein the core 21 having the coil 26 is apparent in the
5 central region. Figure 9 illustrates with the dotted line
6 a variant in which the first brake component 2 is
7 surrounded by a sleeve body 34. The sleeve body 34
8 comprises a radial thickness 34a that is considerably
9 smaller than the gap width 5a or than a diameter 11a of
10 the roller bodies 11. The sleeve body 34 is embodied from
11 a magnetically conductive material. As a consequence,
12 after a magnetic field is applied a (particularly small)
13 part of the magnetic field is directly short-circuited.
14 Since the wall thickness of the sleeve body 34 is selected
15 as particularly thin and in this case is not illustrated
16 to scale, this (small) magnetic short-circuit is not
17 negatively significant. Conversely, it is advantageous
18 that as a consequence a metallic surface may be provided
19 on the entire periphery of the first brake component 2, as
20 a result of which it is possible to avoid any abrasion
21 that may occur in the region of the casting compound.
22 Where applicable, the use of a sleeve body 34 of this type
23 may also lead to omitting the complete filling procedure
24 with a casting compound 28, which also reduces the outlay
25 during the production process. A cover is then placed on
26 the axial ends of the coil so that the interior is sealed
27 in order to prevent the penetration of MRF.

28 Finally, figure 10 illustrates a further exemplary
29 embodiment of a magnetorheological braking device 1 that
30 is likewise embodied in this case as a haptic operating
31 knob 100. The magnetorheological braking device 1 in
32 accordance with figure 10 essentially functions in the
33 same manner as in the above-described exemplary
34 embodiments. One difference with respect to the above-
35 described exemplary embodiments is that a central feed-
36 through 39 is provided, through which a supporting element

1 47 is fed through inclusive (of at least) one supply line.
2 At least one sealing ring 46 may be provided for sealing
3 purposes. The supporting element 47 may be anchored by way
4 of example on the console or the like and supports a user
5 interface 43 on which for example a (touch sensitive)
6 display or an input element is provided.

7 A further difference is that a shaft 40 is provided that
8 is embodied in this case as hollow. The shaft 40 is
9 connected in a rotatably-fixed manner to the second brake
10 component 3 with the result that in the case of a rotation
11 of the second brake component 3, the shaft 40 (that is
12 embodied as hollow) also rotates. The part 41 of an angle
13 sensor, which is connected in a rotatably-fixed manner to
14 said shaft, also rotates with the rotation of the shaft
15 40. For example it is possible for the part 41 to be
16 embodied as a magnetic encoder or the like. The part 41
17 cooperates with the part 42 of an angle sensor, which may
18 be embodied by way of example as a detector. As a
19 consequence, in the case of a rotation of the second brake
20 component 3 a signal is detected by means of the sensor
21 41, 42. In this case, a relative or also an absolute angle
22 signal may be detected. One considerable advantage of such
23 an embodiment having a shaft 40 resides in the fact that
24 the angle sensor is received in a protected manner within
25 the console. As a consequence, contamination does not
26 reach the sensor from the outside, with the result that a
27 reliable operation may be ensured. Where applicable, it is
28 also possible to arrange the parts 41 and 42 in the
29 interior of the holder 4.

30 In the event of only one angle sensor 41, 42 being
31 provided, it is not necessary for the shaft 40 to be
32 embodied as hollow and to be used to feed-through a
33 supporting element 47 for a display/input element. The
34 shaft 40 may also be embodied as solid. A display must
35 then either be fastened and supplied in another manner or
36 said display must be omitted.

1 The user interface 43 may also be used as a pressure
2 element or tension element, which transmits via the
3 supporting element 47 the movement to an encoder/switch
4 that lies below (possibly under the console 50).

5 It is also possible to move (push/pull) the entire braking
6 unit relative to the console 50 in the axial direction as
7 well as in the radial direction, as well as to move the
8 entire unit with or without a console in the radial or
9 axial direction.

10 Conversely, it is also possible to provide a feed-through
11 without the hollow shaft. By way of example if the
12 protected attachment of an angle sensor is omitted or an
13 angle position is detected in another manner.

14 Possible embodiments for controlling a dynamically
15 generated magnetic field or a dynamically generated
16 braking torque in dependence upon the angle of rotation
17 are illustrated in the figures 11a, 11b and 11c.

18 Figure 11a illustrates in this case a variant in which a
19 rotary knob is used as a haptic operating aid. The
20 rotational resistance is illustrated over the angle of
21 rotation. A left-hand side end stop 228 and a right-hand
22 side end stop 229 may be generated using the controller
23 27. A high magnetic field or stopping torque 238 is
24 generated at the rotary knob when the rotary knob 23 is
25 further rotated, as a result of which the rotary knob 23
26 sets a high resistance with respect to a rotational
27 movement. The user obtains the haptic feedback of an end
28 stop.

29 In this case, a magnetic selection of the rotational
30 movement may be provided or generated. By way of example,
31 this may be used in order to navigate through a graphic
32 menu and to select menu points. In this case, a first
33 magnetic selection point 226 is provided directly adjacent

1 to the left-hand side end stop 228, said magnetic
2 selection point corresponding to for example a first menu
3 point during operation. If the next menu point is to be
4 selected, the rotary knob 100 is rotated clockwise. For
5 this purpose, the dynamically generated higher magnetic
6 field or selection torque 239 or the frictional torque
7 thereof must be overcome prior to reaching the next
8 magnetic selection point 226. In figure 11a, a respective
9 constant magnetic field is generated for a specific
10 angular range respectively at the magnetic selection
11 points 226 and at the regions that lie between said
12 magnetic selection points, said magnetic field being
13 considerably smaller at the magnetic selection points than
14 in the regions in between said magnetic selection points
15 and again clearly less than at the stops 228, 229.

16 An angular distance 237 between individual magnetic
17 selection points may be changed dynamically and is adapted
18 to the number of magnetic selection points or menu points
19 that are available.

20 Figure 11b illustrates a variant in which at the end stops
21 228, 229 the magnetic field does not increase abruptly but
22 rather assumes a steep curve. Furthermore, respective
23 ramp-like increases of the magnetic field are provided at
24 the magnetic selection points 226 on both rotational
25 sides, as a result of which the rotational resistance
26 increases in the corresponding rotational directions. In
27 this case, using the same operating device 100 only three
28 magnetic selection points 226 are provided and the angular
29 distance 237 thereof is greater than in the example in
30 accordance with figure 11a.

31 Figure 11c illustrates a variant in which a lower
32 rotational resistance is provided between individual
33 magnetic selection points 226 and an increased magnetic
34 field 239 is only generated directly adjacent to the
35 magnetic selection points 226 respectively in order to

1 render it possible to snap into the individual magnetic
2 selection points 226 and simultaneously to only provide
3 little rotational resistance between individual magnetic
4 selection points.

5 Fundamentally, a mixture of the operating modes and the
6 magnetic field curves of the figures 11a, 11b, 11c is also
7 possible. For example, in the case of different submenus
8 an accordingly different setting of the magnetic field
9 curve may be provided.

10 It is also possible in all cases that, in the event of for
11 example a ripple (selection), a switch is performed unlike
12 as previous between less and more current strength having
13 the same polarity (in other words for example +0.2 to
14 +0.8A = ripple), but rather alternately with a changed
15 polarity, in other words from +0.2 to +0.8A and then the
16 next ripple from -0.2A to -0.8A and then the next torque
17 peak from +0.2 to +0.8 etc.

18 It is also possible in all cases that the operating mode
19 of the figures 11a, 11b and 11c or a mixture of the
20 operating modes are selected by means of voice commands.
21 The user selects a function (volume, transmitter
22 selection...) by voice input (using local or remote voice
23 recognition, for example via Alexa, Amazon Echo, Siri,
24 Google voice input...). The magnetorheological braking
25 device then provides a corresponding operating mode
26 (volume = selection having an increasing braking torque
27 for increasing volume; radio transmitter selection =
28 selection having various increment and therebetween low
29 braking torque until a transmitter is found).

30 The preferably low-alloy steel may contain a residual
31 magnetic field. The steel is preferably demagnetized
32 regularly or as required (*inter alia* by means of a
33 specific alternating field).

1 It is preferred that the material FeSi3P (silicon steel)
2 or a related material is used for the components that the
3 magnetic field flows through.

4 In all cases, a voice control procedure or a sound control
5 procedure may be performed. The braking device may be
6 controlled adaptively using voice control.

7 If the rotary unit is not rotated, in other words the
8 angle is constant, the current is preferably continuously
9 reduced over the time. The current may also be varied in
10 dependence upon speed (rotational angle speed of the
11 rotary unit).

List of reference numerals:

1	Magneto rheological braking device	19	Magnetic particles
2	Brake component	20	Axial direction
2a	Outer diameter	21	Core
3	Brake component	22	Sphere for the bearing arrangement of 3
4	Holder	23	Rotary knob
5	Gap, duct	24	Outer ring
5a	Gap width	26	Coil
5b	Gap length, gap height	27	Control device
6	Medium	28	Casting compound
8	Field	30	Bearing arrangement
9	Free gap	31	Axial groove
10	Acute angled region	32	Transverse groove
11	Transmission component, roller body, rotary body	33	Cylindrical base body
11a	Diameter of 11	34	Sleeve body
11b	Length of 11	34a	Radial thickness of 34
11c	Magnetically non-conductive transmission component	35	Cable feed-through
12	Rotational axis	36	Receiving arrangement
13	Sleeve part	36a	Outer diameter
13a	Inner diameter	37	Cylindrical running surface
13b	Outer diameter	37a	Outer diameter
13c	Height	38	Seal
13d	Wall thickness	39	Feed-through
14	Sphere	40	Shaft
15	Cylinder	41	Part of an angle sensor
16	Chock shape	42	Part of an angle sensor
17	Direction of the relative movement	43	User interface
18	Direction of the relative movement	45	Cable
		46	Sealing ring
		47	Supporting element

	and supply line		point
48	Sliding guide	228	End stop
49	Cover	229	End stop
50	Console	237	Angular distance
100	Haptic operating	238	Stop torque
	knob	239	Selection torque
		240	Base torque
226	Magnetic selection		

Claims:

1. A magnetorheological braking device (1) having a fixed holder (4) and having at least two brake components (2, 3), wherein a first brake component (2) is connected in a rotatably-fixed manner to the holder (4) and extends in an axial direction (20) and wherein the second brake component (3) comprises a sleeve part (13) that is embodied as hollow and that may rotate about the first brake component (2), wherein a gap (5) is embodied between the first and the second brake component (2, 3) and at least one, two or more rotatable transmission components (11) are arranged in said gap (5), and wherein the gap (5) is filled at least in part with a magnetorheological medium (6),
characterized in that
the first brake component (2) comprises a core (21) that extends in the axial direction (20), said core being embodied from a magnetically-conductive material, and an electrical coil (26) that is wound in the axial direction (20) around the core (21), with the result that a magnetic field (8) of the electrical coil (26) extends transversely through the first brake component (2).
2. The magnetorheological braking device (1) as claimed in claim 1, wherein at least one transmission component (11) is embodied as a roller body.
3. The magnetorheological braking device (1) as claimed in the preceding claim, wherein at least one roller body (11) comprises a cylindrical or spherical or round or rounded cross section.
4. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein at least some of the transmission components (11) are embodied from a magnetically conductive material.

5. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein at least some of the transmission components (11c) are embodied from a magnetically non-conductive material.
6. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the sleeve part (13) is embodied on a rotary knob (23).
7. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the sleeve part (13) is embodied from a magnetically conductive material and provides an outer ring (24) for the magnetic field.
8. The magnetorheological braking device (1) as claimed in the preceding claim, wherein at least one radial wall thickness (13a) of the sleeve part (13) is at least half as thick as a gap width (5a) of the gap (5) and/or a diameter (11a) of a transmission component (11).
9. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein a length (2a) of the first brake component (2) in the axial direction (20) is greater than a length (11b) of a transmission component (11) in the axial direction (20).
10. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein a length (5b) of the gap (5) in the axial direction (20) is at least twice as large as a length (11b) of a transmission component (11) in the axial direction (20).
11. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the first brake component (2) is embodied in an essentially cylindrical manner and comprises a cylindrical base body (33) as a core (21) and the electrical coil (26).

12. The magnetorheological braking device (1) as claimed in the preceding claim, wherein the electrical coil (26) is wound in axial grooves (31) and/or transverse grooves (32) of the cylindrical base body (33).
13. The magnetorheological braking device (1) as claimed in the two preceding claims, wherein the axial grooves (31) and/or the transverse grooves (32) are filled at least in part with casting compound (28).
14. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the cylindrical base body (33) is surrounded by a sleeve body (34) that is fixedly connected to the cylindrical base body (33), wherein a radial thickness (34a) of the sleeve body (34) is smaller than half of the radial gap width (5a) of the gap (5).
15. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the holder (4) comprises a cable feed-through (35).
16. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the holder (4) comprises a receiving arrangement (36) for the rotatably-fixed connection to the first brake component (2) and wherein the holder (4) comprises a cylindrical running surface (37) for a bearing arrangement (30) and supports the sleeve part (13) in a rotatable manner on the holder (4).
17. The magnetorheological braking device (1) as claimed in the preceding claim, wherein a seal (38) is arranged on the cylindrical running surface (37) so as to seal the gap (5), wherein the seal (38) is arranged closer to the gap (5) than the bearing arrangement (30).

18. The magnetorheological braking device (1) as claimed in either of the two preceding claims, wherein the cylindrical running surface (37) is hardened and/or comprises a higher surface quality than the radial outer surface of the receiving arrangement.
19. The magnetorheological braking device (1) as claimed in any one of the three preceding claims, wherein the cylindrical running surface (37) comprises an outer diameter (37a) that is at least 3 mm smaller than an outer diameter (36a) of the receiving arrangement (36) of the holder.
20. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the first brake component (2) comprises a feed-through (39) for a shaft (40) that is connected in a rotatably-fixed manner to the second brake component (3).
21. The magnetorheological braking device (1) as claimed in the preceding claim, wherein a part (41) of an angle sensor is attached to the shaft (40).
22. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein the holder (4) is fastened to a console (50).
23. The magnetorheological braking device (1) as claimed in the preceding claim, wherein a further part (42) of an angle sensor is fastened to the holder (4) or the console (50).
24. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein a user interface (43), an operator panel, a display, a touch-sensitive display with or without haptic feedback and/or at least one sensor is attached to the axial end that lies opposite the holder.

25. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein at least one component, which the magnetic field flows through, is embodied at least in part from the material FeSi₃P.
26. The magnetorheological braking device (1) as claimed in any one of the preceding claims, wherein at least one microphone and/or a sound recognition device and/or a voice recognition device is included or allocated.
27. A method for operating appliances using an adaptive braking device having a rotatable brake component for manual rotation, wherein the braking device is controlled in dependence upon the manual rotation of the rotatable brake component and by means of a command that is identified by means of sound recognition.
28. The method as claimed in the preceding claim, wherein voice commands and/or sound signals and/or clapping signals are identified using sound recognition.
29. The method as claimed in either of the two preceding claims, wherein sounds are received and are processed locally and/or remotely.
30. The method as claimed in any one of the three preceding claims, wherein at least one magnetorheological braking device (1) is controlled as claimed in any one of the preceding claims.