



US 20120051952A1

(19) **United States**(12) **Patent Application Publication****Knoop et al.**(10) **Pub. No.: US 2012/0051952 A1**(43) **Pub. Date: Mar. 1, 2012**(54) **CHARGING DEVICE FOR AN ENERGY
CONVERSION DEVICE***F04D 29/32*

(2006.01)

F04D 25/06

(2006.01)

(76) Inventors: **Andreas Knoop**, Esslingen (DE);
Thomas Steidten, Ludwigsburg
(DE); **Reiner Kimmich**,
Bietigheim-Bissingen (DE)(52) **U.S. Cl. 417/365; 415/104; 417/423.12**

(57)

ABSTRACT

A charging device for an energy conversion device, e.g., a fuel cell, of a motor vehicle, has a rotor rotatably mounted on a housing of the charging device, the rotor having a shaft and at least two compressor wheels which are connected in rotationally fixed fashion to the shaft. The compressor wheels have wheel rear parts facing away from respective compressor wheel inlets, by which a medium that is to be supplied to the energy conversion device, e.g., air, is compressible. The wheel rear parts of the compressor wheels are matched to one another such that respective forces which are opposed to one another and which result from respective compressor wheel outlet forces impressed on the wheel rear parts substantially balance one another.

(21) Appl. No.: **13/199,301**(22) Filed: **Aug. 24, 2011**(30) **Foreign Application Priority Data**

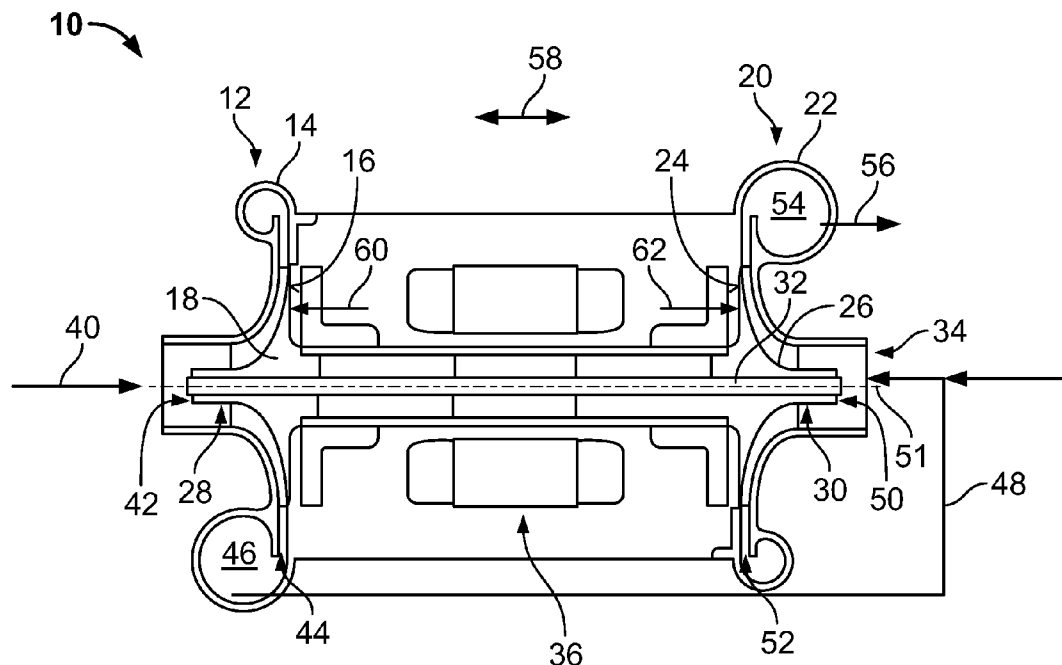
Aug. 28, 2010 (DE) 10 2010 035 725.1

Publication Classification(51) **Int. Cl.***F04D 29/041*

(2006.01)

F04D 29/047

(2006.01)



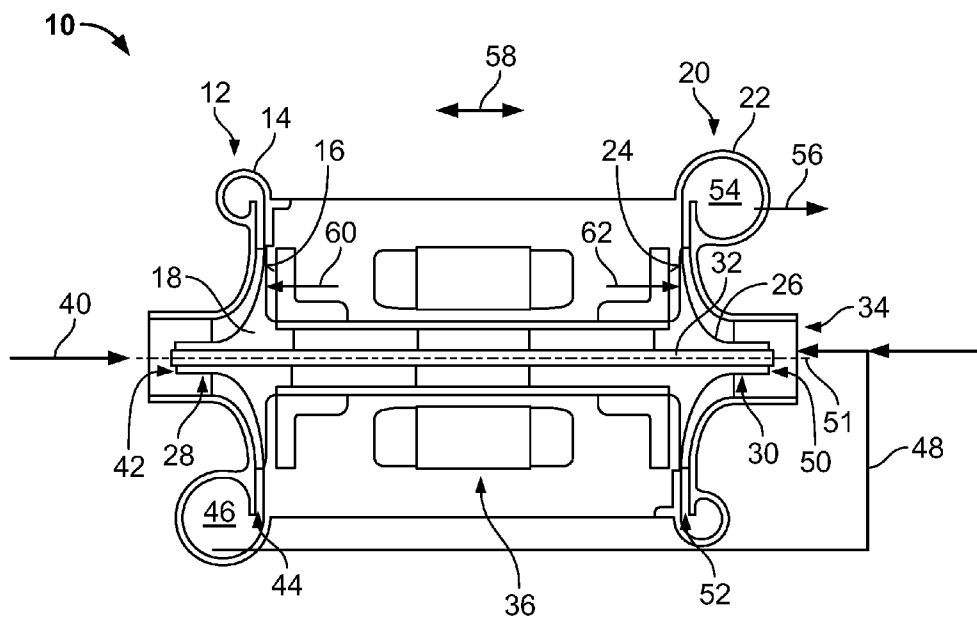


FIG. 1

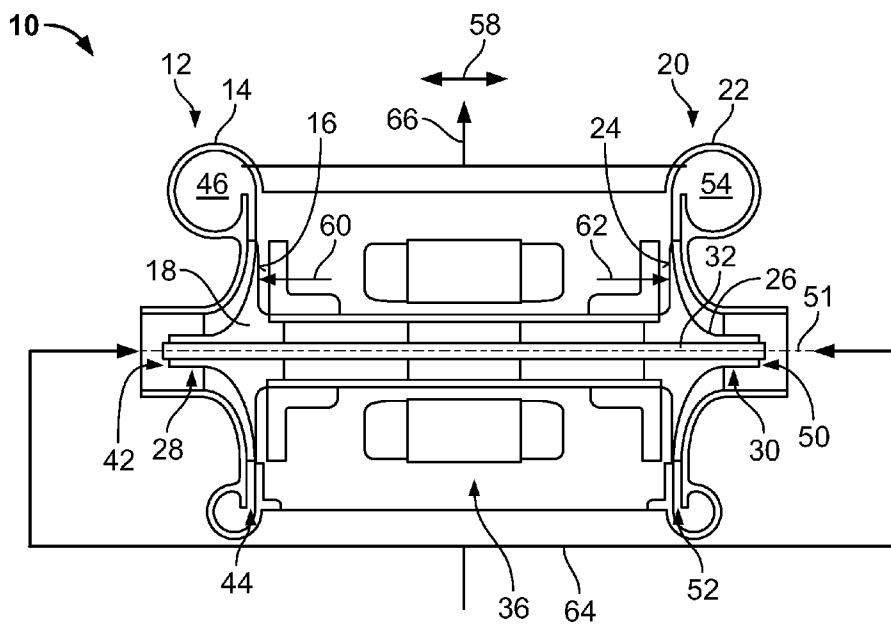


FIG. 2

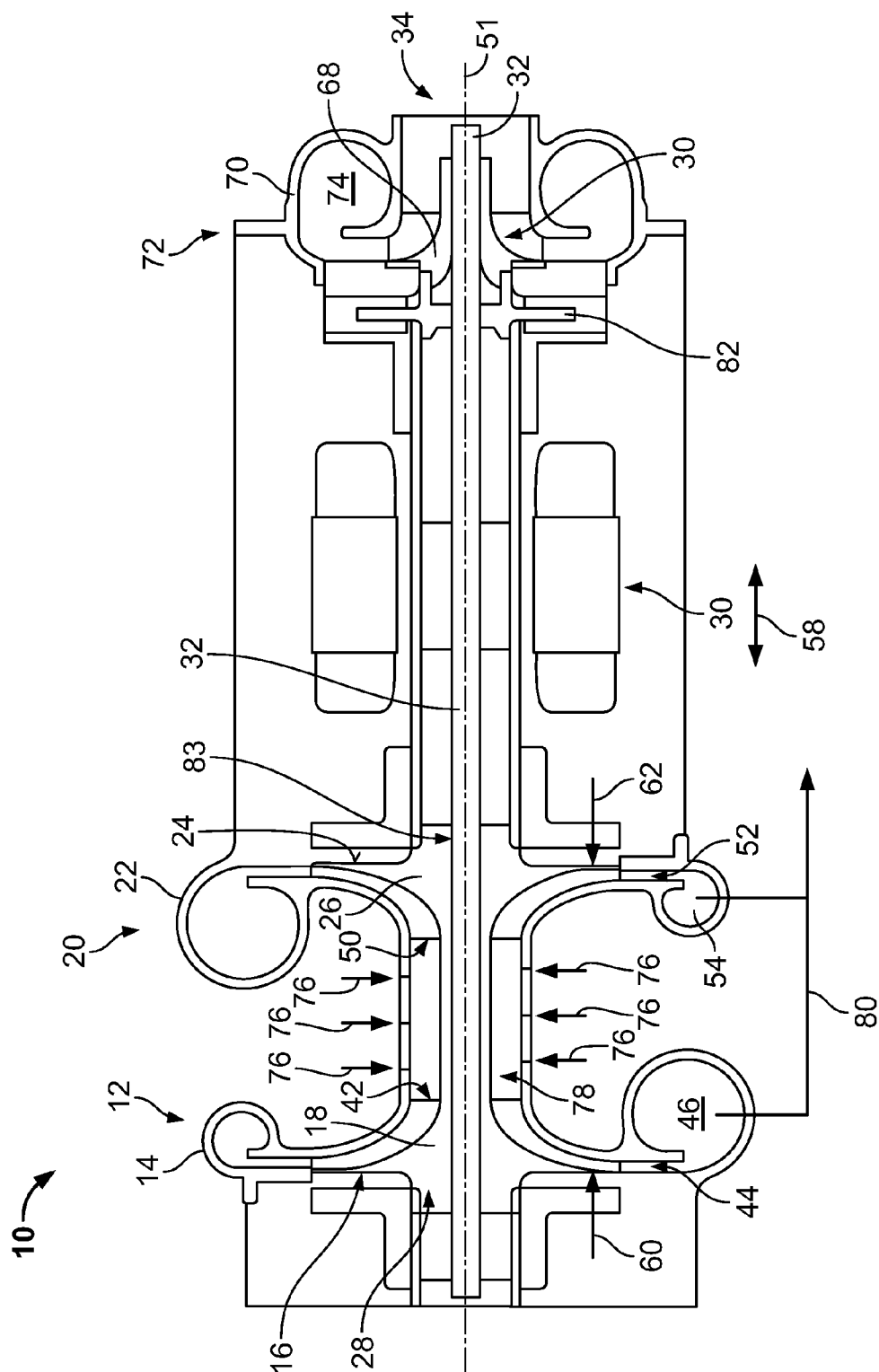


FIG. 3

CHARGING DEVICE FOR AN ENERGY CONVERSION DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a charging device for an energy conversion device, e.g., a fuel cell.

[0003] 2. Description of the Related Art

[0004] Published Japanese patent application JP 2001/263291 discloses a supporting structure for a high-speed compressor having an electric motor that includes a rotor shaft mounted by magnetic bearings.

[0005] U.S. Pat. No. 6,196,809 B1 discloses a two-stage compressor having two compressor wheels that are attached to opposite end regions of a shaft. For the axial mounting, magnetic axial bearings are provided that absorb forces in the axial direction of the shaft.

[0006] U.S. Pat. No. 6,155,802 discloses a turbo compressor having a first and a second compression chamber, and having a shaft that is connected to two compressor wheels.

[0007] U.S. Pat. No. 6,450,780 B1 discloses a method for producing a gas under pressure using a compressor that is coupled to an electrical machine. The compressor includes a rotor having a shaft that is mounted by magnetic bearings. In addition, the rotor includes two compressor wheels that are connected to the shaft in rotationally fixed fashion.

[0008] Published international patent application document WO 03/040567 A1 discloses a two-stage compressor having a shaft. The compressor also includes two compressor wheels by which a fluid is to be compressed. The compressor wheels are connected to the shaft in rotationally fixed fashion.

[0009] The known compressors have further potential for making their operation more efficient.

[0010] Therefore, an object of the present invention is to provide a charging device for an energy conversion device that has particularly efficient operation.

BRIEF SUMMARY OF THE INVENTION

[0011] According to the present invention, a charging device for an energy conversion device, in particular for a fuel cell, of a motor vehicle includes a rotor that is rotatably mounted on a housing of the charging device, said rotor having a shaft and having at least two compressor wheels that are connected to the shaft in rotationally fixed fashion and that each have wheel rear parts facing away from respective compressor wheel inlets, by which wheels a medium that is to be supplied to the energy conversion device, in particular air, can be compressed.

[0012] According to the present invention, it is provided that the wheel rear parts of the compressor wheels are matched to one another, so that respective oppositely oriented forces resulting from compressor wheel outlet pressures impressed on the rear parts of the wheels balance one another, at least substantially. Due to this balancing of the forces acting in particular and at least substantially in the axial direction of the shaft, no forces, or only very small forces, have to be absorbed and supported in this direction. In this way, no, or only very small, frictional losses occur that would occur as a result of forces to be supported, so that a very efficient operation of the charging device results. This is also beneficial for a very efficient operation of the energy conversion device associated with the charging device, so that said energy conversion device can thus be operated in a particu-

larly energy-efficient manner, so that the energy converted by the energy conversion device can for example be used in very large part to drive the motor vehicle, and does not for example remain unused as a result of frictional losses resulting from the described forces.

[0013] This is advantageous in particular if the shaft or the rotor is mounted by at least one air bearing, in particular a dynamic air bearing, having at least one foil for the mounting. As a result of their design, such air bearings produce higher frictional losses than do other kinds of bearings such as ball bearings; the predominant part of these frictional losses, for example two-thirds of the overall frictional losses, occur in particular in the absorption of bearing forces in the axial direction of the shaft.

[0014] Through the use of the compressor wheels having the wheel rear parts matched to one another, it is possible at least largely to cancel the opposed forces, in particular the axial forces, in that the forces counterbalance one another. A result of this is that a corresponding bearing, in particular an axial bearing, for the absorption of these forces can be made correspondingly smaller in its dimensions and therefore less susceptible to losses, or can even be completely omitted. This also results in very low weight as well as, in some cases, a very low part count of the charging device according to the present invention, which on the one hand is beneficial for the efficient operation of the charging device and on the other hand keeps the costs of the charging device, and therefore of the motor vehicle as a whole, low.

[0015] In an advantageous specific embodiment of the present invention, the wheel rear parts are matched to one another with regard to their respective diameter. In this way, the balancing of the oppositely acting forces is realized in a particularly simple and economical manner, reducing the complexity of the charging device as well as its part count, and also keeping low the costs of the charging device. If pressures differing from one another act on the wheel rear parts, then the respective surfaces of the wheel rear parts on which the pressures act are correspondingly to be matched to one another with regard to their surface content, so that from this matching there result opposed forces that balance one another. Here, a design parameter suitable for the matching of the surface contents is the diameter of the wheel rear parts; for example, a larger diameter results in a larger surface, and a comparatively smaller diameter results in a smaller surface. If, for example, a first pressure acts on one of the wheel rear parts that is greater than a second pressure acting on the other wheel rear part, then the surface on which the first pressure acts is correspondingly to be made smaller in its surface content than the surface of the wheel rear part on which the second pressure acts, so that forces result whose magnitudes are equal but that are opposed to one another and therefore counterbalance one another, in particular in the axial direction of the shaft.

[0016] During operation of the charging device for compressing the air, in particular axial forces arise that act in the direction of the respective compressor wheel inlets in the axial direction of the shaft. These axial forces at least substantially counterbalance one another in the charging device according to the present invention, so that a corresponding axial bearing can be omitted, or at least can be made with smaller dimensions.

[0017] If the charging device according to the present invention is used in a motor vehicle during whose operation there may occur non-steady operating states of the energy

conversion device and thus of the charging device, in particular accelerations of the charging device, then a corresponding axial bearing of the rotor may be indispensable in order to prevent contact between the rotor and, in particular, the compressor wheels and the housing of the charging device, and thus to ensure reliable, long-lived operation of the charging device.

[0018] Alternatively or in addition, it can be provided that the rotor is mounted in the radial direction of the shaft by a magnetic bearing, bringing the advantages already described in connection with such a magnetic bearing.

[0019] In an advantageous specific embodiment of the present invention, the rotor is mounted by at least one air bearing, in particular in the axial direction. Such an air bearing, which has for example a foil for bearing the rotor, enables an efficient and reliable bearing of the rotor even, and in particular, at very high rotational speeds of the rotor which occur for the efficient compression of the air.

[0020] In order to enable the air to be compressed particularly efficiently and so as to meet demand, the charging device has for example a motor, in particular an electric motor, by which the rotor can be driven. This enables an operation of the charging device that is efficient and meets the demand for the supply, proportionate to demand, of compressed air to the energy conversion device, resulting in efficient operation of the energy conversion device and thus of the motor vehicle as a whole.

[0021] In a particularly advantageous specific embodiment of the present invention, the compressor wheels for compressing the medium are connected in series to one another, resulting in a two-stage and particularly efficient compression of the medium, in particular air. Here, one of the compressor wheels acts as a first compressor stage and the other compressor wheel acts as the second compressor stage, the diameter of the wheel rear parts, or the diameter of the compressor wheels, being for example correspondingly matched to one another so that forces that occur during compression, in particular axial forces, cancel each other out at least almost completely, advantageously completely.

[0022] It is also possible for the compressor wheels for compressing the medium, in particular air, to be connected parallel to one another. This also enables a particularly advantageous and efficient compression of the air; here, compressor wheels can be used that are at least substantially equal with regard to their diameter, or with regard to the diameter of the wheel rear parts, and that differ only in their direction of rotation. A stream of the medium, in particular air, that is to be compressed is then applied simultaneously and in parallel to these two compressor wheels. In this specific embodiment, a complete compensation is possible of the forces resulting from the compression, in particular the axial forces.

[0023] If the rotor has a turbine wheel that is connected in rotationally fixed fashion to the shaft, by which the rotor can be driven, then in this way the operation of the charging device and in particular of the energy conversion device can be made particularly efficient. Here, for example the exhaust gas of the energy conversion device, in particular the fuel cell, can be used to drive the turbine and, via the turbine, the compressor wheels.

[0024] In the charging device according to the present invention, it can be provided that the compressor wheels are situated in opposite end regions of the shaft. If the turbine wheel is provided, it is possible for the turbine wheel to be situated between the compressor wheels in the axial direction

of the shaft. It can also be provided that, in the axial direction of the shaft, first the first compressor wheel is situated on the shaft and is connected in rotationally fixed fashion thereto, and is followed by the second compressor wheel, situated on the shaft and connected in rotationally fixed fashion thereto, the turbine wheel only then being situated on the shaft in the axial direction and connected in rotationally fixed fashion thereto. These specific embodiments are advantageous and are correspondingly to be selected depending on conditions of space, demands, boundary conditions, and/or the like.

[0025] Here it is to be noted that the compressor wheels and the turbine wheel that may be provided are fashioned as radial compressor wheels or a radial turbine wheel, so that the medium can be compressed particularly efficiently and the charging device requires only very little space. This solves or avoids packaging problems, in particular in space-critical areas of the motor vehicle in which the charging device is situated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. 1 shows a schematic longitudinal sectional view of a charging device that has a first compressor and a second compressor by which air that is to be supplied to a fuel cell can be compressed in two stages, the compressor having respective compressor wheels having wheel rear parts that are matched to one another, through which respective, opposed axial forces resulting from respective compressor outlet pressures impressed on the wheel rear parts balance one another, at least substantially.

[0027] FIG. 2 shows a schematic longitudinal sectional view of another specific embodiment of a charging device as shown in FIG. 1, whose compressors are connected to one another in parallel, the air being compressible by the compressors in one stage.

[0028] FIG. 3 shows a schematic longitudinal sectional view of a further specific embodiment of the charging device in FIG. 2, the charging device having a turbine capable of driving the compressor for compressing the air.

DETAILED DESCRIPTION OF THE INVENTION

[0029] FIG. 1 shows a charging device 10 that is allocated to a fuel cell and by which air that is to be supplied to the fuel cell can be compressed. The fuel cell uses this compressed air supplied to it to convert the oxygen in the air, and the hydrogen supplied to it, into electrical energy.

[0030] Charging device 10 has a compressor 12, fashioned as a radial compressor, having a housing 14 in which a first compressor wheel 18, having a first wheel rear part 16, is accommodated. In addition, charging device 10 has a second compressor 20 fashioned as a radial compressor, having a housing 22 in which a second compressor wheel 26 having a second wheel rear part 24 is accommodated.

[0031] Compressor wheels 18 and 26 are situated in respective end regions 28 and 30 of a shaft 32, on said shaft, and are connected in rotationally fixed fashion thereto, charging device 10 having a rotor 34 to which compressor wheels 16 and 26 and shaft 32 are allocated.

[0032] In addition, charging device 10 has an electric motor 36 by which compressor wheels 18 and 26 for compressing the air can be driven via shaft 32. For this purpose, shaft 32, as well as compressor wheels 18 and 26, rotate about an axis of rotation 51 at very high rotational speeds.

[0033] The air that is to be compressed is supplied to compressor 12, acting as the first compressor stage, in the direction shown by arrow 40, the air flowing to the corresponding compressor wheel 18 via a compressor wheel inlet 42, being compressed by compressor wheel 18, and flowing out of compressor wheel 18 via a compressor wheel outlet 44, into a channel 46. Via channel 46, the air pre-compressed by compressor wheel 18 is guided, in the direction shown by arrow 48, to compressor 20, acting as the second compressor stage. The pre-compressed air flows to compressor wheel 26 via a corresponding compressor wheel inlet 50, is compressed by compressor wheel 26, and flows out of compressor wheel 26 via a corresponding compressor wheel outlet 52 and into a corresponding channel 54, via which the further compressed air is finally supplied to the fuel cell in the direction shown by arrow 56.

[0034] In order to keep frictional losses of charging device 10 low, and thus to realize a particularly efficient operation thereof, wheel rear parts 16 and 24, and thus compression wheels 18 and 26, are matched to one another with regard to their diameter, whereby opposed forces resulting from compressor wheel outlet pressures impressed on each of wheel rear parts 16 and 26 balance one another at least substantially. These forces are axial forces and act in the axial direction of rotor 34 or of shaft 32, in the direction shown by arrow 58, and are indicated in FIG. 1 by arrows 60 and 62. Due to their direction of action in the axial direction, these forces are indicated as axial forces in the direction of arrow 58.

[0035] As can be seen in FIG. 1, the axial forces indicated by arrows 60 and 62 are oriented in opposite directions and act in the direction of the respective compressor wheel inlets 42 and 50 via which air flows to compressor wheels 18 and 26.

[0036] On the basis of the at least substantial balancing of the axial forces, a bearing of rotor 34 for the absorption of these axial forces can be omitted, or can be made particularly small in its dimensions, so that no, or only very small, frictional losses occur as a result of an absorption of the axial forces.

[0037] Due to the two-stage compression of charging device 10 shown in FIG. 1, the compressor wheel outlet pressures prevailing at corresponding compressor wheel outlets 44 and 52 and impressed on wheel rear parts 16 and 24 differ from one another, so that surfaces differing from one another on which the compressor wheel outlet pressures act are fashioned differently from one another as a result of a different realization of the corresponding diameters.

[0038] In contrast to charging device 10 shown in FIG. 1, the charging device shown in FIG. 2 realizes a two-stage compression of the air that is to be supplied to the fuel cell. Compressors 12 and 20, or compressor wheels 18 and 26, are here not connected in series to one another as in FIG. 1, but rather are connected parallel to one another. This means that air that is to be compressed is supplied in the direction of an arrow 64 to compressors 12 and 20, or compressor wheels 18 and 26, in parallel fashion via the respective compressor wheel inlets 42 and 50.

[0039] Compressors 12 and 20 thus compress the supplied air in parallel fashion. Correspondingly, the air compressed in parallel is also led out via channels 46 and 54 in the direction of an arrow 66 and is supplied to the fuel cell. In the one-stage and parallel compression of the air using charging device 10 shown in FIG. 2, as a result of the compressor wheel outlet pressures impressed on wheel rear parts 16 and 24, axial forces (arrows 60 and 62) result that balance one another due

to the matching of wheel rear parts 16 and 24 to one another. In the one-stage compression shown in FIG. 2, it is possible to use compressor wheels 18 and 26 that are at least substantially identical and that differ from one another only with regard to their direction of rotation for compressing the air. The two compressor wheels 18 and 26 of charging device 10 shown in FIG. 2 thus share an air mass flow that is to be compressed and that is to be supplied in the direction of arrow 64, enabling an at least nearly complete compensation of the axial forces.

[0040] Compressors 12 and 20 compress the air to an at least almost identical pressure level, so that the compressor wheel outlet pressures acting on wheel rear parts 16 and 24 are at least substantially equal. Correspondingly, identical surface contents of wheel rear parts 16 and 24 on which the compressor outlet pressures act are sufficient for the at least substantial balancing of the axial forces.

[0041] If charging devices 10 shown in FIGS. 1 and 2 are used for example in a motor vehicle, in particular a passenger vehicle, then during operation of the motor vehicle non-steady operation of charging devices 10 may occur, in which rotor 34 has to be alternately accelerated, braked, accelerated again, etc. As a result of this non-steady operation, despite the corresponding matching of wheel rear parts 16 and 24 to one another (for the balancing of the axial forces in at least approximately steady operation), in some circumstances axial forces may occur that do not balance one another. In some circumstances, this then requires an axial bearing of rotor 34 for, if warranted, a very short-duration absorption and supporting of forces acting in the axial direction along arrow 58. Because, however, these forces may occur only for a very short time due to the matching of wheel rear parts 16 and 24, and their magnitude is small, such an axial bearing can be made small with regard to its dimension and its weight, so that only small frictional losses result from the absorption of these forces, and in addition a particularly efficient operation of charging device 10 is ensured.

[0042] FIG. 3 shows another specific embodiment of charging device 10 shown in FIG. 2, rotor 34 of charging device 10 having a turbine wheel 68 that is connected in rotationally fixed fashion to shaft 32 and is accommodated in a housing 70 of a turbine 72 of charging device 10.

[0043] Turbine 72 with turbine wheel 68 is used to supply exhaust gas from fuel cell 10, via a channel 74 provided through housing 70, to compressor wheel 68, and to drive compressors 12 and 20, or corresponding compressor wheels 18 and 26, in order to compress the air.

[0044] According to charging device 10 shown in FIG. 2, compressors 12 and 20 compress the air in parallel and in one stage, the air being supplied to compressors 12 and 20 in the direction of arrows 76 via a corresponding channel 78. Via channel 78, the air to be compressed flows to compressor wheels 12 and 20 via corresponding compressor wheel inlets 42 and 50.

[0045] When the air is compressed, the air in compressor wheels 12 and 20 flows out as shown via compressor wheel outlets 44 and 52 and is conducted to the fuel cell via channels 46 and 54, in the direction of an arrow 80.

[0046] As can be seen in FIG. 3, compressor wheel 18 is also situated in end region 28 of shaft 32. In end region 30 of shaft 32, however, there is situated not compressor wheel 26 but rather turbine wheel 68, which is connected in rotationally fixed fashion to shaft 32. Compressor wheel 26 is situated, in the axial direction of rotor 34 or of shaft 32, between com-

pressor wheel **18** and turbine wheel **68**, in an intermediate region **83** of shaft **32**, and is connected in rotationally fixed fashion thereto.

[0047] In order to absorb the axial forces that are shown and that occur in particular during non-steady operation, and that do not balance and compensate one another, in FIG. **3** an axial bearing **82** is shown that is capable of absorbing and supporting the axial forces, thus preventing undesired contact of rotor **34**, and in particular compressor wheels **18** and **26**, as well as turbine wheel **68**, with housings **14**, **22**, and **70**.

[0048] Axial bearing **82** shown in FIG. **3**, which can absorb both axial forces in the direction of arrow **60** and those in the direction of arrow **62**, is fashioned for example as an air bearing.

What is claimed is:

1. A charging device for a fuel cell of a motor vehicle, comprising:

a housing; and

a rotor rotatably mounted on the housing, wherein the rotor includes a shaft and at least two compressor wheels connected to the shaft in rotationally fixed fashion, wherein each compressor wheel has a wheel rear part facing away from a respective compressor wheel inlet, wherein the at least two compressor wheels compress air which is to be supplied to the fuel cell, and wherein the wheel rear parts of the two compressor wheels are

matched to one another such that opposing forces resulting from respective compressor wheel outlet pressures impressed on the wheel rear parts substantially balance one another.

2. The charging device as recited in claim 1, wherein the wheel rear parts are matched to one another with regard to their diameter.

3. The charging device as recited in claim 2, wherein the rotor is mounted by at least one air bearing in the axial direction.

4. The charging device as recited in claim 2, wherein the at least two compressor wheels for compressing air are connected in series.

5. The charging device as recited in claim 2, wherein the at least two compressor wheels for compressing air are connected in parallel.

6. The charging device as recited in claim 2, further comprising:

a drive motor configured to drive the rotor.

7. The charging device as recited in claim 2, wherein the rotor has a turbine wheel connected in rotationally fixed fashion to the shaft, and wherein the rotor is driven by the turbine wheel.

8. The charging device as recited in claim 7, wherein the turbine wheel is driven by an exhaust gas of the fuel cell.

* * * * *