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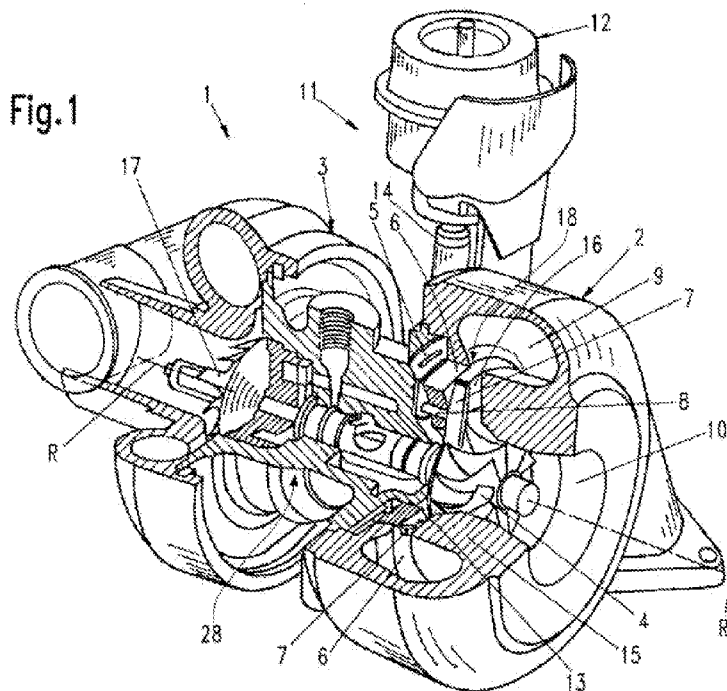
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(54) Title: TURBOCHARGER AND COMPONENT THEREFOR



(57) Abstract: What is described is a component for turbocharger applications, in particular in diesel engines, which consists of an iron-based alloy having a ferritic base structure which comprises a carbide and nitride structure.



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TURBOCHARGER AND COMPONENT THEREFOR

DESCRIPTION

5 The invention relates to a component for turbocharger applications, in particular in a diesel engine, as per the preamble of claim 1, and also to an exhaust-gas turbocharger comprising a component as per the preamble of claim 7.

Exhaust-gas turbochargers are systems intended to increase the power of piston engines. In an exhaust-gas turbocharger, the energy of the exhaust gases is used to increase the power.
10 The increase in power is a result of the increase in the throughput of mixture per working stroke.

A turbocharger consists essentially of an exhaust-gas turbine with a shaft and a compressor, wherein the compressor arranged in the intake tract of the engine is connected to the shaft and the blade wheels located in the casing of the exhaust-gas turbine and the
15 compressor rotate. In the case of a turbocharger having a variable turbine geometry, adjusting blades are additionally mounted rotatably in a blade bearing ring and are moved by means of an adjusting ring arranged in the turbine casing of the turbocharger.

Extremely high demands are made on the material of the components of a turbocharger, and in particular of the kinematics components or of the wastegate components thereof, or, in
20 the case of a VTG turbocharger, also of the VTG components thereof. The material of these components has to be heat-resistant, i.e. it still has to afford sufficient strength and therefore dimensional stability even at very high temperatures of up to about 900°C. Furthermore, the material has to have a high resistance to wear and also appropriate oxidation resistance, so that the corrosion or wear on the material is reduced even at the high operating temperatures
25 of several hundred °C, and therefore the resistance of the material remains ensured under the extreme operating conditions.

DE 10 2004 062 564 A1 discloses a blade bearing ring for a turbocharger having good thermal stability and low sliding wear. In this type of blade bearing ring, use is made of an austenitic material, an iron-based alloy which has a high sulfur content for improving the
30 lubricating action of the component. Owing to the specific composition, the creep resistance of the material is increased and therefore an increased dimensional stability of the blade bearing ring is achieved at temperatures of above 850°C.

In view of this, it is an object of the present invention to provide a component for turbocharger applications as per the preamble of claim 1 and also a turbocharger as per the
35 preamble of claim 7, which have an improved temperature and oxidation resistance and therefore also a very good dimensional stability and high-temperature strength, and also corrosion resistance, are distinguished by optimum tribological properties and additionally show a reduced susceptibility to wear.

The object is achieved by the features of claim 1 and of claim 7.

An improved temperature resistance of the material and in particular improved sliding wear properties and a reduced tendency toward oxidation are achieved by the embodiment according to the invention, in the form of a component for turbocharger applications or of an exhaust-gas turbocharger comprising such a component, consisting of an iron-based alloy having a ferritic base structure which comprises a carbide and nitride structure. Within the context of the invention, a carbide structure or nitride structure is understood to mean in this case a microstructural carbide precipitation phase or nitride precipitation phase which is formed in the grain and at the grain boundaries of the iron-based alloy. The carbide structure is, in particular, a dendritic microstructure, as a result of which a very good resistance of the material and therefore of the component to deformation and wear is also obtained. Provision is therefore made of a component for turbocharger applications, or an exhaust-gas turbocharger which comprises at least one component according to the invention, which has an optimum temperature resistance up to 900°C, also has a high high-temperature strength, has a high wear and corrosion resistance and is distinguished in addition by very good sliding properties with a reduced tendency toward oxidation, in particular at the high operating temperatures. Furthermore, the component according to the invention and therefore the exhaust-gas turbocharger according to the invention are also dimensionally stable in long-term operation.

Without being bound to theory, it is assumed that the presence of carbide precipitations and also nitride precipitations in the ferritic iron-based alloy considerably increases the stability of the alloy material and therefore the stability of the component, in particular to friction wear, and also the high-temperature strength thereof on account of this unique structure.

By way of example, the iron-based alloy according to the invention, i.e. the ferritic iron-based material having a carbide and nitride structure which forms the component, is distinguished by a maximum sliding wear rate of 0.08 mm in diameter given a contact pressure of 20 MPa, a sliding speed of 0.0025 m/s, a component temperature of about 850°C and 2 000 000 cycles, i.e. an extraordinary resistance to friction wear. In addition, the high-temperature strength, the dimensional stability and also the high-temperature performance are also improved.

The dependent claims relate to advantageous developments of the invention.

Thus, in one embodiment, the wear properties of the component, i.e. specifically the resistance thereof to friction wear, can be improved considerably by the use of at least one of the elements tungsten (W), titanium (Ti) and niobium (Nb) in the ferritic iron-based alloy from which the component according to the invention is formed. The elements W, Ti and Nb substantially form the carbide formations in the iron-based alloy, which, in addition to the very good wear performance, also increases the corrosion resistance of the material and therefore of the component according to the invention.

In a further embodiment, the component according to the invention for turbocharger applications is distinguished by the fact that it comprises at least one of the elements selected from: C, W, Cr, Mn, Ti, V, Nb and Si. The presence of at least one of these elements is to be understood as meaning that such an element or a combination of these elements is used to produce the iron-based alloy, which is then processed to form the component according to the invention. The elements added to the iron-based alloy can be present here in their original form, i.e. in elemental form, for example in the form of inclusions or precipitation phases, or else in the form of derivatives thereof, i.e. in the form of a compound of the corresponding element, e.g. as a metal carbide or metal nitride, which form either during the production of the iron-based alloy or else when forming the component according to the invention which is produced therefrom. The presence of the elements can be detected directly in this case in the component according to the invention by conventional analytical methods.

The element carbon serves here primarily for forming the carbide structure according to the invention, i.e. the carbidic precipitation phases, and therefore improves the strength of the material and also the high-temperature strength thereof, and therefore of the component according to the invention for turbocharger applications. The element tungsten, too, mostly as a result of the formation of carbidic structures, increases the high-temperature strength and wear resistance of the material and contributes to the toughness thereof. A combination of tungsten with chromium and/or molybdenum, in particular, makes it possible to considerably improve the corrosion resistance of the material in acid media, and also the hot corrosion performance. The use of chromium here increases the high-temperature tensile strength and the scaling resistance of the material. Chromium is additionally a strong carbide former, and therefore the wear properties of the material, and therefore of the component according to the invention, are also optimized thereby. The use of the element chromium in the iron-based alloy from which the component according to the invention for turbocharger applications is formed has yet another advantage: under the action of high exhaust-gas temperatures on the component, the chromium forms a Cr_2O_3 surface layer, i.e. an oxidic surface layer on the component, which efficiently promotes the resistance of the component to sliding friction and friction wear under thermal loading. The use of manganese has a deoxidizing effect. It expands the gamma region of the iron-based alloy and increases the yield strength and tensile strength of the material. In addition, manganese promotes the wear resistance of the component, in particular at high operating temperatures. Vanadium refines the primary grain of the iron-based alloy during the production thereof and therefore refines the cast structure thereof. This achieves a high degree of grain refinement, which promotes the homogeneity of the iron-based alloy and permits a higher dynamic contact pressure of the material. In the iron-based alloy which forms the component according to the invention, the element niobium acts as a carbide former and therefore promotes the carbide structure in the grain and at the grain boundaries of the iron-based alloy. Niobium also increases the high-temperature

strength and the fatigue strength of the material, and therefore also of the component according to the invention for turbocharger applications. Niobium furthermore promotes the ferrite formation and reduces the gamma region of the iron-based alloy, and can therefore be used in a regulative capacity. Silicon promotes the casting properties of the iron-based alloy by reducing the viscosity of the melt during casting. In addition, silicon in the material according to the invention promotes deoxidation, and therefore the addition of this element to the alloy decisively improves the resistance to hot corrosion. By suitably selecting and combining the elements, the properties of the iron-based alloy can therefore be controlled in a targeted manner, such that the component according to the invention for turbocharger applications and therefore also the exhaust-gas turbocharger according to the invention have a particularly balanced profile of properties. Further elements, and also compounds, can be introduced into the iron-based alloy.

According to a further embodiment, the component according to the invention for turbocharger applications is distinguished by the fact that it comprises substantially the elements carbon (C) with 0.1 to 0.5% by weight, in particular with 0.25 to 0.4% by weight, chromium (Cr) with 15 to 22% by weight, in particular with 18 to 20% by weight, manganese (Mn) with at most 1.3% by weight, in particular with at most 1% by weight, silicon (Si) with 0.8 to 2.1% by weight, in particular with 1 to 1.8% by weight, niobium (Nb) with 0.4 to 1.3% by weight, in particular with 0.6 to 1.1% by weight, titanium (Ti) with 0.2 to 0.6% by weight, in particular with 0.3 to 0.5% by weight, tungsten (W) with 1.8 to 3.0% by weight, in particular with 2 to 2.7% by weight, vanadium (V) with 0.3 to 1.0% by weight, in particular with 0.5 to 0.8% by weight, nitrogen (N) with at most 3% by weight, in particular with at most 2% by weight, and iron (Fe) as the remainder. The indications of quantity in each case relate here to the overall weight of the iron-based alloy from which the component according to the invention is formed. As already stated, the presence of said elements is to be understood as meaning that they can be present both in elemental form and also in the form of one of the compounds thereof in the iron-based alloy, and therefore in the component according to the invention for turbocharger applications. In this embodiment, substantially the aforementioned elements are present in the component according to the invention in the quantities indicated. This means that unavoidable impurities may be present, although these preferably make up less than 2% by weight and in particular less than 1% by weight, based on the overall weight of the iron-based alloy. The unavoidable residues or impurities in this case comprise, for example, aluminum (Al), nickel (Ni), zirconium (Zr), cerium (Ce), boron (B), phosphorus (P) and sulfur (S). The quantities of the individual elements can in this case be detected directly in the component according to the invention by means of conventional elemental analysis methods.

It has surprisingly been found that precisely the described combination provides a material, i.e. an iron-based alloy, which, when it is processed to form a component for

turbocharger applications, provides said component with a particularly balanced profile of properties. This composition according to the invention provides a component which has a particularly high high-temperature strength, a temperature resistance up to 900°C and therefore dimensional stability at a high temperature, and which is distinguished by outstanding sliding properties and therefore particularly low sliding wear. In addition, the corrosion resistance and oxidation resistance are maximized, in particular at high operating temperatures, as act during operation of a turbocharger on the corresponding component.

A material which is produced in this way and from which the component according to the invention is formed thus has the following properties:

Mechanical property	Value	Measurement process
Tensile strength R_m	> 650 MPa	ASTM E 8M / EN 10002-1; at elevated temp.: EN 10002-5
Yield strength $R_{p 0.2}$	> 270 MPa	Standard process
Elongation at break	> 12%	Standard process
Hardness	225-265 HB	ASTM E 92 / ISO 6507-1
Coefficient of linear expansion	10.5-14 K ⁻¹ (20 to 900°C)	Standard process

According to a further embodiment of the invention, the component for turbocharger applications is substantially free of sigma phases. This applies in particular to the operation of the component according to the invention up to 900°C. This effectively counteracts embrittlement of the material, as a result of which the durability of the component is increased. Sigma phases are brittle, intermetallic phases of high hardness. They arise when a body-centered cubic metal and a face-centered cubic metal, whose atomic radii match with only a slight discrepancy, strike one another. Sigma phases of this type are undesirable since they have an embrittling effect and also because of the property of the iron matrix to withdraw chromium. The iron-based alloy according to the invention and therefore also the component according to the invention are substantially free of sigma phases, such that the undesirable effects described here fail to appear. The reduction in or prevention of the formation of sigma phases is controlled, in particular, by a targeted selection of the elements of the iron-based alloy, and in particular is achieved in that the silicon content in the alloy material is at most 2.1% by weight and preferably at most 1.8% by weight, based in each case on the overall weight of the iron-based alloy.

What is therefore described according to the invention is a component for turbocharger applications which is distinguished by an outstanding wear performance, i.e. a high sliding wear resistance even at high temperatures of up to 900°C, a high high-temperature strength

and also dimensional stability and furthermore by an excellent oxidation resistance and corrosion resistance. By virtue of these outstanding properties, the component according to the invention is suitable in particular for those components for turbocharger applications which are exposed to high temperatures of up to 900°C and/or high levels of friction.

5 Exemplary components comprise kinematics components, wastegate components and VTG components, and in particular VTG components and flap mount parts.

The iron-based alloy can be produced and processed to form the component according to the invention for turbocharger applications by means of conventional processes. To ensure dimensional stability, age-annealing can be carried out at 900°C for about 2 hours, with
10 subsequent air cooling, in order to generate secondary precipitations. The material can be welded by means of TIG, plasma and EB welding processes.

As an object which can be dealt with independently, claim 7 defines an exhaust-gas turbocharger comprising at least one component, as already described, which consists of an iron-based alloy having a ferritic base structure and comprises a carbide and nitride structure.

15 The advantageous embodiments of the component according to the invention are also applicable in the embodiments of the exhaust-gas turbocharger according to the invention.

Figure 1 shows a perspective view, shown partially in section, of an exhaust-gas turbocharger according to the invention. Figure 1 shows a turbocharger 1 according to the invention, which has a turbine casing 2 and a compressor casing 3 which is connected to the
20 latter via a bearing casing 28. The casings 2, 3 and 28 are arranged along an axis of rotation R. The turbine casing is shown partially in section in order to illustrate the arrangement of a blade bearing ring 6 and a radially outer guide grate 18, which is formed by said ring and has a plurality of adjusting blades 7 which are distributed over the circumference and have rotary
25 axles 8. In this way, nozzle cross sections are formed which, depending on the position of the adjusting blades 7, are larger or smaller and act to a greater or lesser extent upon the turbine rotor 4, positioned in the center on the axis of rotation R, with the exhaust gas from an engine, said exhaust gas being supplied via a supply duct 9 and discharged via a central
30 connection piece 10, in order to drive a compressor rotor 17 seated on the same shaft using the turbine rotor 4.

In order to control the movement or the position of the adjusting blades 7, an actuating
35 device 11 is provided. This may be designed in any desired way, but a preferred embodiment has a control casing 12 which controls the control movement of a tappet member 14 fastened to it, in order to convert the movement of said tappet member on an adjusting ring 5, located behind the blade bearing ring 6, into a slight rotational movement of the latter. A free space
13 for the adjusting blades 7 is formed between the blade bearing ring 6 and an annular part 15 of the turbine casing 2. So that this free space 13 can be ensured, the blade bearing ring 6 has spacers 16.

- Example -

Unless specified otherwise, the indications of quantity of the individual elements relate in each case to the overall weight of the iron-based alloy.

5 An iron-based alloy from which a plurality of components according to the invention for turbocharger applications, specifically flap shaft, flap plate and bush, were formed was produced from the following elements by a common process. The chemical analysis yielded the following values for the elements: C: 0.25 to 0.4% by weight, Cr: 18 to 20% by weight, Mn: less than 1% by weight, Si: 1 to 1.8% by weight, Nb: 0.6 to 1.1% by weight, Ti: 0.3 to 10 0.5% by weight, W: 2 to 2.7% by weight, V: 0.5 to 0.8% by weight, N: ≤ 3% by weight, and Fe as the remainder. In addition, unavoidable residues of Al, Ni, Zr, Ce, B, P and S were found in traces with a proportion of less than 1% by weight.

The components produced in accordance with this example were distinguished by the following properties:

15

Property	Measured value (measurement process)
Tensile strength R_m at 20°C	655 MPa (ASTM E 8M / EN 10002-1)
Yield strength R_p 0.2 at 20°C	277 MPa (standard process)
Elongation at break	13.5% (standard process)
Hardness	248 HB (ASTM E 92 / ISO 6507-1)
Coefficient of linear expansion at 20°C	12.6 K ⁻¹ (standard process)
High-temperature strength R_m at 900°C	123 MPa (EN 10002-5)
High-temperature strength R_m at 800°C	188 MPa (EN 10002-5)
High-temperature strength R_m at 700°C	257 MPa (EN 10002-5)
High-temperature strength R_m at 600°C	333 MPa (EN 10002-5)
High-temperature strength R_m at 500°C	395 MPa (EN 10002-5)
High-temperature strength R_m at 400°C	443 MPa (EN 10002-5)
Yield strength R_p 0.2 at 900°C	83 MPa (standard process)
Yield strength R_p 0.2 at 800°C	115 MPa (standard process)
Yield strength R_p 0.2 at 700°C	174 MPa (standard process)
Yield strength R_p 0.2 at 600°C	229 MPa (standard process)
Yield strength R_p 0.2 at 500°C	281 MPa (standard process)
Yield strength R_p 0.2 at 400°C	360 MPa (standard process)

The material was subjected to a validation test series which comprised the following tests:

20

- Open-air weathering test
- Climate change test
- Thermal shock test/cycle test – 300 h
- Hot-gas corrosion test in a cracking furnace
- 5 - Strauss test according to DIN EN ISO 3651-2
- Vibration friction wear test on a tribometer: bush/shaft at operating temperature (900°C)

10 The respective component was distinguished in all tests by an outstanding resistance to the acting forces. The material therefore had an extremely high wear resistance and outstanding oxidation resistance, such that corrosion and wear/friction wear to the material were reduced considerably under the indicated conditions, and therefore the resistance of the material and therefore also of the component formed therefrom also remained ensured over a long time.

15 Thermal cycle test:

The components (shaft/bush) according to the invention were subjected to a thermal cycle test, in which the thermal shocks were carried out as follows:

- 20 1. use of stationary rotors;
2. 2-EGT operation;
3. test duration: 350 h (approximately 2000 cycles);
4. throughout the test, the exhaust-gas flap of the EGTs remains open by 15°;
- 25 5. high temperature: rated power point T3 = 750°C, mass flow EGT on the turbine side: 0.5 kg/s;
6. low temperature: T3 = 100°C, mass flow EGT on the turbine side: 0.5 kg/s;
7. cycle duration: 2 x 5 min. (10 min.);
8. three intermediate crack tests are carried out.

30 Given the following load collective, the respective component (shaft/bush) according to the invention was distinguished by a low high-temperature oxidation, i.e. an oxidation rate of at most 40 µm, in particular of at most 35 µm, at a component temperature of 900°C:

Parameter	Result
Bearing load	10-18 N/mm ²
Sliding speed	0.0025 m/s
Component temperature	500-900°C

Surface roughness	Rz 6.3
Test medium	Diesel exhaust gas
Test duration	500 h
Clock frequency	0.2 Hz
Adjustment angle	45°
Friction value	< 0.18
Journal diameter	4.7 mm
Pressure pulsation	> 200 bar
Exhaust-gas pressure	1.5 bar
Wear rate	< 0.08 mm

The results indicated here verify that the component according to the invention is ideally suited for turbocharger applications in a temperature range of up to 900°C.

List of reference signs

	1	Turbocharger
	2	Turbine casing
5	3	Compressor casing
	4	Turbine rotor
	5	Adjusting ring
	6	Blade bearing ring
	7	Adjusting blades
10	8	Pivot axles
	9	Supply duct
	10	Axial connection piece
	11	Actuating device
	12	Control casing
15	13	Free space for guide blades 7
	14	Tappet member
	15	Annular part of the turbine casing 2
	16	Spacer/spacer cam
	17	Compressor rotor
20	18	Guide grate
	28	Bearing casing
	R	Axis of rotation

CLAIMS

1. A component for turbocharger applications, in particular in diesel engines, consisting of an iron-based alloy having a ferritic base structure comprising a carbide and nitride structure.
2. The component for turbocharger applications as claimed in claim 1, comprising at least one of the elements selected from: W, Ti and Nb.
3. The component for turbocharger applications as claimed in claim 1 or 2, comprising at least one of the elements selected from: C, W, Cr, Mn, Ti, V, Nb and Si.
4. The component for turbocharger applications as claimed in one of the preceding claims, wherein it comprises substantially the following elements:
- C: 0.1 to 0.5% by weight, in particular 0.25 to 0.4% by weight,
Cr: 15 to 22% by weight, in particular 18 to 20% by weight,
Mn: $\leq 1.3\%$ by weight, in particular $\leq 1\%$ by weight,
Si: 0.8 to 2.1% by weight, in particular 1 to 1.8% by weight,
Nb: 0.4 to 1.3% by weight, in particular 0.6 to 1.1% by weight,
Ti: 0.2 to 0.6% by weight, in particular 0.3 to 0.5% by weight,
W: 1.8 to 3.0% by weight, in particular 2 to 2.7% by weight,
V: 0.3 to 1.0% by weight, in particular 0.5 to 0.8% by weight,
N: $\leq 3\%$ by weight, in particular $\leq 2\%$ by weight, and
Fe: ad 100% by weight.
5. The component for turbocharger applications as claimed in one of the preceding claims, wherein it is substantially free of sigma phases.
6. The component for turbocharger applications as claimed in one of the preceding claims, wherein the component is a kinematics component and/or a wastegate component and/or a VTG component, in particular a VTG component and/or a flap mount part.
7. An exhaust-gas turbocharger in particular for diesel engines, comprising at least one component consisting of an iron-based alloy having a ferritic base structure comprising a carbide and nitride structure.

8. The exhaust-gas turbocharger as claimed in claim 7, wherein the component comprises at least one of the elements selected from: W, Ti and Nb and in particular at least one of the elements selected from: C, W, Cr, Mn, Ti, V, Nb and Si.

5 9. The exhaust-gas turbocharger as claimed in claim 7 or 8, wherein the component comprises substantially the following elements:

C: 0.1 to 0.5% by weight, in particular 0.25 to 0.4% by weight,

Cr: 15 to 22% by weight, in particular 18 to 20% by weight,

Mn: $\leq 1.3\%$ by weight, in particular $\leq 1\%$ by weight,

10 Si: 0.8 to 2.1% by weight, in particular 1 to 1.8% by weight,

Nb: 0.4 to 1.3% by weight, in particular 0.6 to 1.1% by weight,

Ti: 0.2 to 0.6% by weight, in particular 0.3 to 0.5% by weight,

W: 1.8 to 3.0% by weight, in particular 2 to 2.7% by weight,

V: 0.3 to 1.0% by weight, in particular 0.5 to 0.8% by weight,

15 N: $\leq 3\%$ by weight, in particular $\leq 2\%$ by weight, and

Fe: ad 100% by weight.

10. The exhaust-gas turbocharger as claimed in one of claims 7 to 9, wherein the component is substantially free of sigma phases.

20

