An adjustment ring for turbocharger applications, particularly in diesel engines, is described, which consists of an iron-based alloy with an austenitic basic structure with dendritic carbide precipitations.
TURBOCHARGER AND ADJUSTMENT RING THEREFOR

[0001] The invention relates to an adjustment ring for turbocharger applications, particularly in a diesel engine, according to the preamble of claim 1, and also to an exhaust gas turbocharger having an adjustment ring, according to the preamble of claim 5.

[0002] Exhaust gas turbochargers are systems for increasing the power of piston engines. In an exhaust gas turbocharger, the energy of the exhaust gases is utilized in order to increase the power. The power increase results from a rise in the mixture throughput per working stroke.

[0003] A turbocharger consists essentially of an exhaust gas turbine with a shaft and compressor, the compressor arranged in the intake tract of the engine being connected to the shaft, and the blade wheels located in the casing of the exhaust gas turbine and in the compressor rotating. In a turbocharger with variable turbine geometry, adjustable blades are additionally mounted rotatably in a blade bearing ring and are moved by means of an adjustment ring arranged in the turbine casing of the turbocharger.

[0004] The adjustment ring has to satisfy extremely stringent material requirements. The material forming the adjustment ring must be heat-resistant, that is to say still show sufficient strength even at very high temperatures of up to about 900°C. Furthermore, the material must have high wear resistance and also corresponding oxidation resistance, so that the corrosion or wear of the material is reduced, and, consequently, the resistance of the material under the extreme working conditions is still ensured. These physical properties of the material are also to be reflected in the component, that is to say the adjustment ring.

[0005] Heat-resistant materials for exhaust gas turbochargers or their individual components are known from EP 1 396 620 A1. What is considered suitable here is a material which has a specific composition, the surface of the components being capable of being coated with a chrome carbide layer, and the material having a low fraction of small, non-metallic inclusions. A heat resistance of the turbocharger or of its individual components of up to 700°C or more is thereby to be achieved.

[0006] By contrast, the object of the present invention is to provide an adjustment ring according to the preamble of claim 1 or a turbocharger according to the preamble of claim 5, which has improved temperature and oxidation resistance, and corrosion resistance under extreme temperatures, and also corresponding wet corrosion resistance, which is distinguished by optimal tribological properties and, moreover, which exhibits a reduced susceptibility to wear.

[0007] The object is achieved by means of the features of claim 1 and claim 5.

[0008] By virtue of the design according to the invention of an adjustment ring or an exhaust gas turbocharger comprising just such an adjustment ring, a better temperature resistance of the component is achieved. This is increased further by a multiple by means of the dendritic carbide precipitations contained in the iron-based alloy, that is to say a carbide microstructure contained in the iron-based alloy and having a high ramification of the M23C6 carbide structure and, furthermore, disperions of nitrogen in the form of nitride structures. An adjustment ring is thus provided, or an exhaust gas turbocharger is provided which contains the adjustment ring according to the invention which has optimal temperature resistance in the range of up to 900°C, furthermore is highly heat-resistant, has high wear and corrosion resistance and, moreover, is also distinguished by very good sliding properties, along with reduced oxidizability.

[0009] Furthermore, the adjustment ring according to the invention remains dimensionally stable and therefore highly planar, that is to say is distinguished by a high strength of the material forming it.

[0010] Without being involved in theory, it is presumed that carbide precipitations in the form of dendrites increase the stability of the iron-based alloy in that they form in the microstructure of the material fine ramifications which perform a supporting action, so that, consequently, the strength of the material and therefore the strength of the adjustment ring according to the invention are markedly increased on account of the unique structure of the latter. The dispersions of the element nitrogen in the form of nitride structures in this case additionally increase the wear performance and corrosion resistance.

[0011] The maximum wear rate of the adjustment ring according to the invention in this case amounts to less than 0.14 mm for a bearing load of about 40 N/mm², a sliding speed of 0.0025 m/s, a component temperature of about 500 to 900°C, a surface roughness Ra of 0.5, a test duration of 500 hours, a clock frequency of 0.2 Hz, an adjustment angle of 45°, a coefficient of friction of 0.28, a journal diameter of 4.7 mm, a pressure pulsation of more than 200 mbar and an exhaust gas pressure of more than 1.5 bar, with a diesel exhaust gas as the test medium.

[0012] During a thermal shock cycle test with a test time of 300 hours, the material plainness of the adjustment ring according to the invention amounts to less than 0.14 mm in the case of a circumference with the diameter of 80 mm.

[0013] The material of the adjustment ring according to the invention has a carbide hardness of the dendritic carbide precipitations of 450 HV1. This very high value ensures the deformation resistance and high wear resistance of the material.

[0014] The material of the adjustment ring according to the invention can be welded by means of conventional welding methods such as WIG, plasma and also EB methods.

[0015] The subclaims contain advantageous developments of the invention.

[0016] In one embodiment, the adjustment ring is distinguished by a specific composition which contains the components C: 0.4 to 1.7% by weight, Cr: 23 to 43% by weight, Ni: 5 to 15% by weight, Mn: 8 to 16% by weight, Si: ≥1.3% by weight, Mo: 0.45 to 4% by weight, W: 0.3 to 3.1% by weight, and Fe.

[0017] The influence of the individual elements on an iron-based alloy is known, but it was then found, surprisingly, that exactly the composition described produces a material which, when processed into an adjustment ring, has a particularly balanced property profile. By means of this composition according to the invention, an adjustment ring with particularly high heat resistance and temperature resistance, even up to 900°C, is obtained, which is distinguished by very good sliding properties and therefore very low sliding wear or wear due to attrition. Moreover, the corrosion resistance is improved, and this also particularly applies to wet corrosion. The material and consequently the adjustment ring according
to the invention are, moreover, highly dimensionally stable, and the material therefore has high strength and deformation resistance.

These properties can even be improved. For this purpose, in one embodiment, the adjustment ring according to the invention consists of a material which contains the following elements: C: 0.6 to 1.5% by weight, Cr: 26 to 38% by weight, Ni: 5 to 13% by weight, Mn: 10 to 14.5% by weight, Si: ≤1% by weight, Mo: 0.75 to 3.5% by weight, W: 0.5 to 2.0% by weight, and Fe.

An adjustment ring produced in this way shows not only the high heat resistance of up to 900°C, but also markedly improved sliding properties. The sliding wear is minimized here. Moreover, here, the corrosion resistance and, in particular, also the oxidation resistance are maximized. These properties accompany the very good dimensional stability and deformation resistance of the adjustment ring according to the invention at high temperatures.

A material produced in this way, and consequently the adjustment ring according to the invention, thus have the following properties:

<table>
<thead>
<tr>
<th>Mechanical properties</th>
<th>Value</th>
<th>Measurement method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength $R_m$</td>
<td>&gt;795 MPa</td>
<td>ASTM E 8M EN 10002-1 at increased temperature EN 10002-5</td>
</tr>
<tr>
<td>Yield point $R_{0.2}$</td>
<td>&gt;650 MPa</td>
<td>Standard method</td>
</tr>
<tr>
<td>Elongation at break</td>
<td>≥5%</td>
<td>Standard method</td>
</tr>
<tr>
<td>Hardness</td>
<td>300 to 385 HB</td>
<td>ASTM E 92/ISO 6507-1</td>
</tr>
<tr>
<td>Coefficient of linear expansion</td>
<td>16 to 19 K^-1</td>
<td>Standard method</td>
</tr>
<tr>
<td></td>
<td>(20 to 900°C)</td>
<td></td>
</tr>
</tbody>
</table>

According to a further embodiment of the invention, the adjustment ring according to the invention or the material forming it, the iron-based alloy, is free of sigma phases. Sigma phases are brittle, intermetallic phases of high hardness. They arise when a body-centered cubic metal and a face-centered cubic metal, the atomic radii of which are identical with a slight deviation, meet one another. Such sigma phases are undesirable because of their embrittling action and also on account of the property of the matrix to extract chrome. According to this further advantageous embodiment, therefore, the material according to the invention is distinguished in that it is free of sigma phases. This counteracts the embrittling of the material and increases its durability. The reduction or avoidance of sigma phases is achieved in that the silicon content in the alloy material is lowered to less than 1.3% by weight and preferably to less than 1% by weight. Furthermore, it is advantageous here to employ austenite formers, such as, for example, manganese, nitrogen and nickel, if appropriate in combination.

Claim 5 defines, as an independently handleable article, an exhaust gas turbocharger which, as already described, comprises an adjustment ring which consists of an austenitic basic structure and which has or contains dendritic carbide precipitations.

FIG. 1 shows a perspective view, illustrated partially in section, of an exhaust gas turbocharger according to the invention. FIG. 1 illustrates the turbocharger 1 according to the invention which has a turbine casing 2 and a compressor casing 3 connected thereto 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 make clear the arrangement of a blade bearing ring 6 and a radially outer guide blade cascade 18 which is formed by the latter and which has a plurality of adjustable blades 7 distributed over the circumference and having rotary axes 8. Nozzle cross sections are thereby formed, which are larger or smaller, depending on the position of the adjustable blades 7, and which act upon the turbine rotor 4, located in the center on the axis of rotation R, to a greater or lesser extent with the engine exhaust gas supplied via a supply duct 9 and discharged via a central connection piece 10, in order via the turbine rotor 4 to drive a compressor rotor 17 seated on the same shaft.

In order to control the movements or position of the adjustable blades 7, an actuating device 11 is provided. This may per se be of any desired design, but a preferred embodiment has a control casing 12 which controls the control movement of a tapet member 14 fastened to it, in order to convert the movement of said tapet member on an adjustment ring 5 located behind the blade bearing ring 6 into a slight rotational movement of said adjustment ring. Between the blade bearing ring 6 and an annular part 15 of the turbine casing 2, a free space 13 for the adjustable blades 7 is formed. So that this free space 13 can be safeguarded, the blade bearing ring 6 has spacers 16.

Example

An alloy was produced from the following elements according to a customary method, an adjustment ring according to the invention being formed from this alloy. The chemical analysis gave the following values for the elements: C: 0.7 to 1.2% by weight; Cr: 27 to 33% by weight; Ni: 7 to 11% by weight; Mn: 10 to 14% by weight; Si: max. 1% by weight; Mo: 0.75 to 1.7% by weight; W: 0.5 to 1.5% by weight; the rest: iron.

The adjustment ring produced according to this example was distinguished by a tensile strength $R_m$ of 805 MPa (ASTM E 8M EN 10002-1; at increased temperature EN 10002-5). The yield point $R_{0.2}$ (measured according to standard methods) amounted to 661 MPa. The elongation at break of the material (measured according to standard methods) amounted to 5.2%. The hardness of the material (measured according to ASTM E 92/ISO 6507-1) amounted to 364 HB. The coefficient of linear expansion (measured according to standard methods) amounted to 17.8 K^-1 (20 to 900°C).

The material was subjected to a validation test series which comprised the following tests: outdoor exposure test, changing climate test, thermal shock test/cycle test—300 h, hot gas corrosion test in a fission furnace.

The component was distinguished, in all the tests, by excellent resistance to the acting forces. The material thus had extremely high wear resistance and outstanding oxidation resistance, so that corrosion and wear of the material under the specified conditions were markedly reduced, and, consequently, the resistance of the material was still ensured even over a long period of time.

Thermal cycle test:

1. Use of stationary rotors;
2. 2-turbocatalyst operation;
3. Test duration: 350 h (approximately 2000 cycles);
4. During the entire test the exhaust gas flap in the turbochargers remains open at 15°;
5. High temperature: nominal power point T3=750° C., turbocharger mass flow on the turbine side: 0.5 kg/s;
6. Low temperature: T3=100° C., turbocharger mass flow on the turbine side: 0.5 kg/s;
7. Cycle duration: 2x5 min. (10 min.);
8. Execution of three intermediate crack tests.

LIST OF REFERENCE SYMBOLS

- 0034: Turbocharger
- 0035: Turbine casing
- 0036: Compressor casing
- 0037: Turbine rotor
- 0038: Adjustment ring
- 0039: Blade bearing ring
- 0040: Adjustable blades
- 0041: Rotary axes
- 0042: Supply duct
- 0043: Axial connection piece
- 0044: Actuating device
- 0045: Control casing
- 0046: Free space for adjustable blades
- 0047: Tappet member
- 0048: Annular part of the turbine casing
- 0049: Spacer-spacing boss
- 0050: Compressor rotor
- 0051: Guide blade cascade
- 0052: Bearing casing
- 0053: Axis of rotation

1. An adjustment ring for turbocharger application, particularly in diesel engines, consisting of an iron-based alloy with an austenitic basic structure and dendritic carbide precipitations.
2. The adjustment ring as claimed in claim 1, which contains the following components:
   - C: 0.4 to 1.7% by weight, Cr: 23 to 43% by weight, Ni: 5 to 15% by weight,
   - Mn: 8 to 16% by weight, Si: ≤1.3% by weight, Mo: 0.45 to 4% by weight,
   - W: 0.3 to 3.1% by weight, and Fe.
3. The adjustment ring, as claimed in claim 1, which contains the following components:
   - C: 0.6 to 1.5% by weight, Cr: 26 to 38% by weight, Ni: 5 to 13% by weight,
   - Mn: 10 to 14.5% by weight, Si: ≤1% by weight, Mo: 0.75 to 3.5% by weight,
   - W: 0.5 to 2.6% by weight, and Fe.
4. The adjustment ring as claimed in claim 1, wherein the iron-based alloy is free of sigma phases.
5. An exhaust gas turbocharger, particularly for diesel engines, comprising an adjustment ring consisting of an iron-based alloy with an austenitic basic structure and dendritic carbide precipitations.
6. The exhaust gas turbocharger as claimed in claim 5, wherein the adjustment ring contains the following components:
   - C: 0.4 to 1.7% by weight, Cr: 23 to 43% by weight, Ni: 5 to 15% by weight,
   - Mn: 8 to 16% by weight, Si: ≤1.3% by weight, Mo: 0.45 to 4% by weight,
   - W: 0.3 to 3.1% by weight, and Fe.
7. The exhaust gas turbocharger as claimed in claim 5, wherein the adjustment ring contains the following components:
   - C: 0.6 to 1.5% by weight, Cr: 26 to 38% by weight, Ni: 5 to 13% by weight,
   - Mn: 10 to 14.5% by weight, Si: ≤1% by weight, Mo: 0.75 to 3.5% by weight,
   - W: 0.5 to 2.6% by weight, and Fe.
8. The exhaust gas turbocharger as claimed in claim 5, wherein the material of the adjustment ring is free of sigma phases.

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