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Amended claims in accordance with Rule 137(2) EPC.

(54) **STAINLESS STEEL ALLOYS, TURBOCHARGER TURBINE HOUSINGS FORMED FROM THE STAINLESS STEEL ALLOYS, AND METHODS FOR MANUFACTURING THE SAME**

(57) Disclosed is an austenitic stainless steel alloy that includes, by weight, about 22% to about 28% chromium, about 3.5% to about 6.5% nickel, about 1% to about 6% manganese, about 0.5% to about 2.5% silicon, about 0.3% to about 0.6% carbon, about 0.2% to about

0.8% nitrogen, and a balance of iron. Molybdenum, niobium, and tungsten are excluded. The alloy is suitable for use in turbocharger turbine housing applications for temperature up to about 980°C.

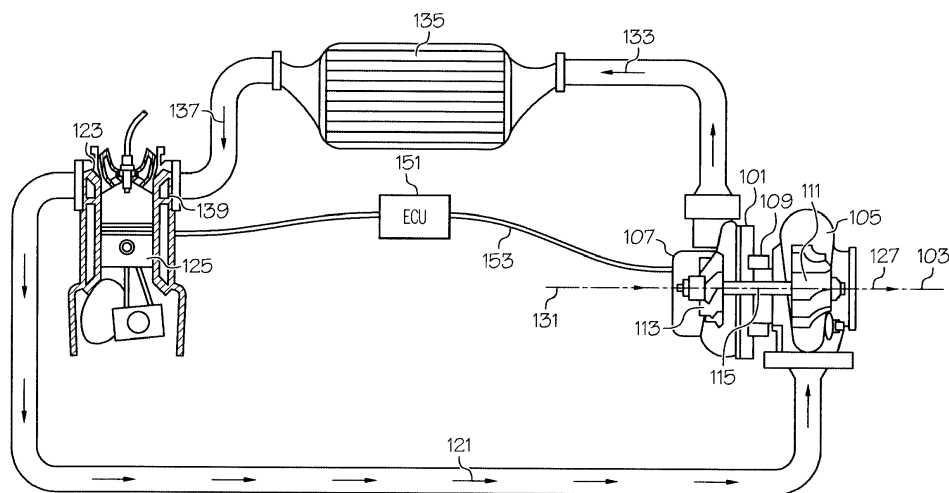


FIG. 1

Description

TECHNICAL FIELD

[0001] The present disclosure generally relates to stainless steel alloys. More particularly, the present disclosure relates to stainless steel alloys used for casting applications, for example turbine and turbocharger turbine housings, exhaust manifolds, and combustion chambers, that exhibit oxidation resistance at elevated temperatures, and method for manufacturing the same.

BACKGROUND

[0002] During operation, automotive or aircraft turbocharger housings are subjected to elevated operating temperatures. These housings must be able to contain a turbine wheel generating very high rotational speeds. Exhaust gas from the automotive or aircraft engine initially contacts the turbocharger in metal sections, such as the gas inlet area of the turbocharger, at elevated temperatures. As high-speed performance improves through exhaust temperature increase, there have been attempts to gradually raise the exhaust temperature of the engine. Due to these high temperatures, the thermal load on the parts such as the exhaust manifold and the turbine housing becomes very great and thermal fatigue resistance and brittleness are important factors.

[0003] Various problems have been encountered by these increased exhaust gas temperatures contacting metal sections of the turbocharger. For example, one problem caused by the exhaust temperature rise is the problem of thermal deformation of the material, wherein the turbine housing and exhaust manifold, which alternates between regions of high temperature and low temperature is accompanied by thermal expansion and thermal shrinkage depending on the situation, which can cause surface oxidation wrinkles by such thermal deformation, and which can progress and develop into a penetration crack.

[0004] In order to overcome the challenges associated with higher operating temperatures, prior art alloys used in turbocharger applications have included alloys of higher nickel content such as commercially available high nickel ductile iron casting alloys. Examples of these are NiResist™ developed by the International Nickel Company, or HK30, a chromium-nickel-iron stainless steel alloy containing approximately 25% chromium and 20% nickel, with the balance essentially iron. The HK series stainless steel alloys in general have about 18-22% nickel and are fully austenitic.

[0005] The HK stainless steel alloys are strong stainless steel casting alloys, in terms of creep strength. However, while meeting the high temperature property requirements for turbocharger housings, they are quite technically expensive because of their high nickel content. Furthermore, it has been found advantageous to exclude some metal components so as to provide im-

proved material properties including thermal fatigue resistance and lack of brittleness.

[0006] Accordingly, there is a need for stainless steel alloys useful in turbocharger applications that are able to withstand the higher operating temperatures produced by modern engines, but that minimize the expensive nickel content. Furthermore, other desirable features and characteristics, such as material properties of the inventive subject matter will become apparent from the subsequent detailed description of the inventive subject matter and the appended claims, taken in conjunction with the accompanying drawings and this background of the inventive subject matter.

BRIEF SUMMARY

[0007] The present invention in its various aspects is as set out in the appended claims.

[0008] Stainless steel alloys, turbocharger turbine housings, and methods of manufacturing turbocharger turbine housings are provided.

[0009] In an embodiment, by way of example only, an austenitic stainless steel alloy includes, by weight, about 22% to about 28% chromium, about 3.5% to about 6.5% nickel, about 1% to about 6% manganese, about 0.5% to about 2.5% silicon, about 0.3% to about 0.6% carbon, about 0.2% to about 0.5% nitrogen, and a balance of iron. Molybdenum, niobium, and tungsten are excluded.

[0010] Niobium, in the presence of silicon can form niobium silicide which has a relatively low density, may affect thermal fatigue resistance and has low creep strength.

[0011] In another embodiment, by way of example only, a turbocharger turbine housing includes an austenitic stainless steel alloy that includes, by weight, about 22% to about 28% chromium, about 3.5% to about 6.5% nickel, about 1% to about 6% manganese, about 0.5% to about 2.5% silicon, about 0.3% to about 0.6% carbon, about 0.2% to about 0.5% nitrogen, and a balance of iron. Molybdenum, niobium, and tungsten are excluded.

[0012] In yet another embodiment, a method of fabricating a turbocharger turbine housing include forming the turbocharger turbine housing from an austenitic stainless steel alloy that includes, by weight, about 22% to about 28% chromium, about 3.5% to about 6.5% nickel, about 1% to about 6% manganese, about 0.5% to about 2.5% silicon, about 0.3% to about 0.6% carbon, about 0.2% to about 0.5% nitrogen, and a balance of iron. Molybdenum, niobium, and tungsten are excluded.

[0013] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The inventive subject matter will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

FIG. 1 is a system view of an embodiment of a turbocharged internal combustion engine in accordance with the present disclosure.

DETAILED DESCRIPTION

[0015] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. As used herein, the word "exemplary" means "serving as an example, instance, or illustration." Thus, any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments. Furthermore, as used herein, numerical ordinals such as "first," "second," "third," etc., such as first, second, and third components, simply denote different singles of a plurality unless specifically defined by language in the appended claims. All of the embodiments and implementations of the stainless steel alloys, turbocharger turbine housings, and methods for the manufacture thereof described herein are exemplary embodiments provided to enable persons skilled in the art to make or use the invention and not to limit the scope of the invention, which is defined by the claims. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary, or the following detailed description.

[0016] The turbocharger turbine housing, usually a cast stainless steel or cast iron, is the most expensive component of the turbocharger. Reduction in cost of the housing will have a direct effect on the cost of the turbocharger. In order to withstand the high operating temperatures commonly produced by exhaust gasses impinging on the turbine housing, turbine housing materials are usually alloyed with elements such as chromium and nickel in addition to other carbide forming elements, which may reduce optimal properties, particularly for use in turbocharger turbines and turbocharger turbine housings.

[0017] Typical embodiments of the present disclosure reside in a motor vehicle equipped with a gasoline powered internal combustion engine ("ICE") and a turbocharger. The turbocharger is equipped with a unique combination of features that may, in various embodiments, provide efficiency benefits by relatively limiting the amount of (and kinetic energy of) secondary flow in the turbine and/or compressor, as compared to a comparable unimproved system.

[0018] With reference to FIGS. 1-2, an exemplary embodiment of a turbocharger 101 having a radial turbine

and a radial compressor includes a turbocharger housing and a rotor configured to rotate within the turbocharger housing around an axis of rotor rotation 103 during turbocharger operation on thrust bearings and two sets of journal bearings (one for each respective rotor wheel), or alternatively, other similarly supportive bearings. The turbocharger housing includes a turbine housing 105, a compressor housing 107, and a bearing housing 109 (i.e., a center housing that contains the bearings) that connects the turbine housing to the compressor housing. The rotor includes a radial turbine wheel 111 located substantially within the turbine housing 105, a radial compressor wheel 113 located substantially within the compressor housing 107, and a shaft 115 extending along the axis of rotor rotation 103, through the bearing housing 109, to connect the turbine wheel 111 to the compressor wheel 113.

[0019] The turbine housing 105 and turbine wheel 111 form a turbine configured to circumferentially receive a high-pressure and high-temperature exhaust gas stream 121 from an engine, e.g., from an exhaust manifold 123 of an internal combustion engine 125. The turbine wheel 111 (and thus the rotor) is driven in rotation around the axis of rotor rotation 103 by the high-pressure and high-temperature exhaust gas stream, which becomes a lower-pressure and lower-temperature exhaust gas stream 127 and is axially released into an exhaust system (not shown).

[0020] The compressor housing 107 and compressor wheel 113 form a compressor stage. The compressor wheel, being driven in rotation by the exhaust-gas driven turbine wheel 111, is configured to compress axially received input air (e.g., ambient air 131, or already-pressurized air from a previous-stage in a multi-stage compressor) into a pressurized air stream 133 that is ejected circumferentially from the compressor. Due to the compression process, the pressurized air stream is characterized by an increased temperature over that of the input air.

[0021] Optionally, the pressurized air stream may be channeled through a convectively cooled charge air cooler 135 configured to dissipate heat from the pressurized air stream, increasing its density. The resulting cooled and pressurized output air stream 137 is channeled into an intake manifold 139 on the internal combustion engine, or alternatively, into a subsequent-stage, in-series compressor. The operation of the system is controlled by an ECU 151 (engine control unit) that connects to the remainder of the system via communication connections 153.

[0022] Turbochargers can be designed to operate at a variety of temperatures, depending on the configuration of the turbocharger and the desired output. As used herein, the term operating temperature refers to the maximum temperature of exhaust gas designed to be experienced by the turbine housing and blade components of the turbocharger. Stainless steel 1.4826, well-known in the art, with its specification for nickel between 8% and 12% is

an exemplary prior art material for turbine housing applications up to about 980°C. The present invention includes a turbocharger comprising the turbocharger turbine housing of the claimed compositions that operates at a temperature of up to about 980°C.

[0023] The presence of carbide forming elements such as niobium (Nb), tungsten (W) and molybdenum (Mo) can be disadvantageous, particularly in the proposed end use. Thus alloys with other materials but that retain the same beneficial properties are desirable. TABLE 1, set forth below, provides the specifications for stainless steel 1.4826.

Table 1: Composition of 1.4826 Stainless Steel

Elements	1.4826	
	Min (%)	Max (%)
Carbon	0.3	0.50
Silicon	1	2.50
Chromium	18	23.0
Nickel	8	12.0
Molybdenum	0	0.50
Manganese	0	2.00
Niobium	1.3	1.70
Phosphorous	0	0.04
Sulphur	0	0.04
Nitrogen	-	-
Iron	Rest	

[0024] As such, embodiments of the present disclosure are directed to improvements over the currently available stainless steel alloys for use in turbochargers having operating temperatures up to about 980°C. In particular, embodiments of the present disclosure are directed to stainless steel alloys that have a nickel content that is less than stainless steel 1.4826 for cost considerations, and eliminates the need for other expensive materials such as W and Mo. The stainless steel alloys described herein include iron alloyed with various alloying elements, as are described in greater detail below in weight percentages based on the total weight of the alloy.

[0025] In an embodiment, the stainless steel alloy of the present disclosure includes from about 0.3% to about 0.6% carbon (C), for example about 0.4% to about 0.5% C. C has a function of improving the fluidity and castability of a melt. C also has a function of improving the castability by forming eutectic carbides. To exhibit such functions effectively, the amount of C should be 0.3% or more. Further, C is effective for strengthening a material by solid solution strengthening. C is an element capable of improving the high-temperature strength and the thermal fatigue resistance. To maximize the corrosion resistance,

the content of C is lowered to 0.6% or about 0.6% and below. As can be seen C has several advantageous properties, particularly thermal fatigue resistance in turbocharger components, whilst materials such as tungsten, niobium and molybdenum can bind C and hence limit the availability of C for that benefit. Whilst tungsten, niobium and molybdenum may be beneficial in some instances and for the alloys of the present invention, particularly when used for turbocharger turbine and turbocharger housings, there is a preferential benefit from the availability of C, at least between 0.3 and 0.6% in and the absence of niobium and preferably also of tungsten and molybdenum.

[0026] In an embodiment, the stainless steel alloy of the present disclosure includes from about 0.5% to about 2.5% silicon (Si), for example about 1.0% to about 2.0% Si. Si has effects of increasing the stability of its metal structure and its oxidation resistance. Further, it has a function as a deoxidizer and also is effective for improving castability and reducing pin holes in the resulting cast products, when present in an amount greater than about 0.5%. If the content of Si is excessive, Si deteriorates the mechanical property such as impact toughness of steel. Therefore, the content of Si is preferably limited to about 2.5% and below.

[0027] In an embodiment, the stainless steel alloy of the present disclosure includes from about 22% to about 28% chromium (Cr), for example about 23% to about 27% Cr, such as from about 24% to about 26% Cr. On the other hand, if it is added excessively, coarse primary carbides of Cr are formed, resulting in extreme brittleness. When the content of Cr increases, the corrosion resistance increases, but the content of expensive Ni should be also increased to maintain the volume fraction. As such, the content of Cr is preferably limited to a maximum of about 28% so as to maintain the volume fraction of the stainless steel and the corrosion resistance.

[0028] In an embodiment, the stainless steel alloy of the present disclosure includes from about 3.5% to about 6.5% nickel (Ni), for example about 4.0% to about 6.0% Ni, such as from about 4.5% to about 5.5% Ni. Ni, together with manganese and nitrogen (which as described in greater detail below are included in the alloy of the present disclosure), is an element to stabilize the austenite phase. To reduce a production cost, if the content of expensive Ni is lowered, the decrement of Ni can be replaced by increasing the content of manganese and nitrogen that form the austenite phase. However, if the content of Ni is excessively lowered, manganese and nitrogen would be excessively needed so that the corrosion resistance and the hot formability characteristics are deteriorated. Thus, the content of Ni preferably ranges from about 3.5% to about 6.5%.

[0029] In an embodiment, the stainless steel alloy of the present disclosure preferably excludes (or at least substantially excludes) molybdenum (Mo), which is a relatively expensive material, to reduce technical costs and potential brittleness.

[0030] In an embodiment, the stainless steel alloy of the present disclosure includes from about 1.0% to about 6.0% manganese (Mn), for example about 1.5% to about 5.5% Mn, such as from about 2.0% to about 5.0% Mn. Mn is effective like Si as a deoxidizer for the melt, and has a function of improving the fluidity during the casting operation. To exhibit such function effectively, the amount of Mn is about 6.0% or less, preferably 5.0% or less. Mn generally has a content of greater than about 1.0% to adjust a metal flow rate. However, when the content of Mn is excessive, Mn is combined with sulfur of the steel and forms excessive levels of manganese sulfide, thereby deteriorating the corrosion resistance and the hot formability. Thus, the upper limit content of Mn is limited to 6.0%.

[0031] In an embodiment, the stainless steel alloy of the present disclosure preferably excludes (or at least substantially excludes) tungsten (W), which is a relatively expensive material, to further reduce costs and may bind with carbon to reduce its availability to adjust other alloy properties.

[0032] In an embodiment, the stainless steel alloy of the present disclosure preferably excludes (or at least substantially excludes) niobium (Nb), which is a relatively expensive material, such as to reduce or avoid niobium silicide and or carbide formation.

[0033] Nitrogen (N) is an element capable of improving the high-temperature strength and the thermal fatigue resistance like C, and such effects can be obtained when the amount of N is 0.2% or more. Accordingly, in an embodiment, the stainless steel alloy includes, in various alternative embodiments, from about 0.2% to about 0.5% N, for example from about 0.3% to about 0.5% N, from about 0.4% to about 0.5% N, from about 0.3% to about 0.4% N, from about 0.2% to about 0.4%, or from about 0.2% to about 0.3%. To ensure the production stability and to avoid the brittleness due to the precipitation of Cr nitrides, the upper limit of N should be about 0.5%. N, together with Ni, is one of elements that contribute stabilization of an austenite phase. As the content of N increases, the corrosion resistance and high strengthening are achieved. However, when the content of N is too high, the hot formability of steel is deteriorated, thereby lowering the production yield thereof. Therefore, the content of N preferably ranges up to a maximum of about 0.5%.

[0034] Certain impurities may also be present in the stainless steel alloy of the present disclosure. The amounts of such impurities are minimized as much as practical. In an embodiment, phosphorus (P) may be present in the alloy, but is minimized to about 0.03% or less. P is seeded in the grain boundary or an interface, and is likely to deteriorate the corrosion resistance and toughness. Therefore, the content of P is lowered as low as possible. Preferably, the upper limit content of P is limited to 0.03% in consideration of the efficiency of a refining process. The contents of harmful impurities, such as P are as small as possible. However, due to cost concerns associated with removal of these impurities, and

the P content is limited to 0.03%.

[0035] In an embodiment, sulfur (S) may be present in the alloy, but is minimized to about 0.03% or less. S in steels deteriorates hot workability and can form sulfide inclusions that influence pitting corrosion resistance negatively. It should therefore be limited to less than 0.03%. S deteriorates the hot formability, or forms MnS together with Mn, thereby deteriorating the corrosion resistance. Therefore, the content of S is lowered as low as possible. The contents of harmful impurities, such as S (sulfur), are as small as possible. However, due to cost concerns associated with removal of these impurities, the S content is limited to about 0.03%.

[0036] Boron (B), calcium (Ca), and cerium (Ce) can optionally be added in very small quantities in steels to improve hot workability. The preferred levels are for B, Ca, and Ce are less than about 0.005%. In the presence of boron, molybdenum borosilicides may be formed which may be brittle and may not be desirable.

[0037] TABLE 2 sets forth the composition of an exemplary embodiment of the present disclosure, in accordance with the description provided above.

Table 2. Composition of Exemplary Stainless Steel Alloy

Elements	Min (%)	Max (%)
Carbon	0.4	0.5
Silicon	1.0	2.0
Chromium	24.0	26.0
Nickel	4.5	5.5
Molybdenum	-	-
Manganese	2.0	5.0
Tungsten	-	-
Niobium	-	-
Phosphorous		0.03
Sulphur		0.03
Nitrogen	0.3	0.5
Boron		0.005
Iron	Rest	

[0038] As such, embodiments of the present disclosure provide numerous benefits over the prior art, such as stainless steel 1.4826. For example, in accordance with the present disclosure, the presently described embodiments lower the nickel content in as compared to stainless steel 1.4826. Further, the amount of molybdenum, niobium, and tungsten are reduced to zero. Thus, due to lower cost, alloys in accordance with the present disclosure are a suitable lower cost option for turbine housing materials for operation up to about 980°C.

[0039] While at least one exemplary embodiment has

been presented in the foregoing detailed description of the inventive subject matter, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the inventive subject matter in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the inventive subject matter. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the inventive subject matter as set forth in the appended claims.

Claims

1. An austenitic stainless steel alloy, comprising, by weight:

about 22% to about 28% chromium;
about 3.5% to about 6.5% nickel;
about 1% to about 6% manganese;
about 0.5% to about 2.5% silicon;
about 0.3% to about 0.6% carbon;
about 0.2% to about 0.5% nitrogen; and
a balance of iron, with the proviso that molybdenum, niobium, and tungsten are excluded from the alloy.

2. The austenitic stainless steel alloy of claim 1 comprising about 23% to about 27% chromium.

3. The austenitic stainless steel alloy of claim 1 comprising about 4.0% to about 6.0% nickel.

4. The austenitic stainless steel alloy of claim 1 comprising about 1.5% to about 5.5% manganese.

5. The austenitic stainless steel alloy of claim 1 comprising about 1.0% to about 2.0% silicon.

6. The austenitic stainless steel alloy of claim 1 comprising about 0.4% to about 0.5% carbon.

7. The austenitic stainless steel alloy of claim 1 comprising about 0.3% to about 0.5% nitrogen.

8. An turbocharger turbine housing comprising:

an austenitic stainless steel alloy, wherein the austenitic stainless steel alloy comprises, by weight:

about 22% to about 28% chromium;
about 3.5% to about 6.5% nickel;

about 1% to about 6% manganese;
about 0.5% to about 2.5% silicon;
about 0.3% to about 0.6% carbon;
about 0.2% to about 0.5% nitrogen; and
a balance of iron, with the proviso that molybdenum, niobium, and tungsten are excluded from the alloy.

9. The turbocharger turbine housing of claim 8 comprising about 23% to about 27% chromium.

10. The turbocharger turbine housing of claim 8 comprising about 4.0% to about 6.0% nickel.

11. The turbocharger turbine housing of claim 8 comprising about 1.5% to about 5.5% manganese.

12. The turbocharger turbine housing of claim 8 comprising about 1.0% to about 2.0% silicon.

13. The turbocharger turbine housing of claim 8 comprising about 0.4% to about 0.5% carbon.

14. The turbocharger turbine housing of claim 8 comprising about 0.3% to about 0.5% nitrogen.

15. A method of fabricating a turbocharger turbine housing, the method comprising the step of:

forming the turbocharger turbine housing from an austenitic stainless steel alloy, wherein the austenitic stainless steel alloy comprises, by weight:

about 22% to about 28% chromium;
about 3.5% to about 6.5% nickel;
about 1% to about 6% manganese;
about 0.5% to about 2.5% silicon;
about 0.3% to about 0.6% carbon;
about 0.2% to about 0.5% nitrogen; and
a balance of iron, with the proviso that molybdenum, niobium, and tungsten are excluded from the alloy optionally further comprising forming a turbocharger turbine using the turbocharger turbine housing.

Amended claims in accordance with Rule 137(2) EPC.

1. An austenitic stainless steel alloy, consisting of, by weight:

24% to 26% chromium;
3.5% to 6.5% nickel;
1.0% to 6.0% manganese;
1.0% to 2.0% silicon;

- 0.3% to 0.6% carbon;
 0.2% to 0.5% nitrogen;
 0.03% sulfur or less;
 0.03% phosphorous or less;
 optionally, one or more of boron, calcium, and cerium, each, if provided, in an amount of 0.005% or less; and
 a balance of iron and inevitable/unavoidable impurities, with the proviso that molybdenum, niobium, and tungsten are excluded from the alloy. 5 10
2. The austenitic stainless steel alloy of claim 1 consisting of 4.0% to 6.0% nickel.
3. The austenitic stainless steel alloy of claim 1 consisting of 1.5% to 5.5% manganese. 15
4. The austenitic stainless steel alloy of claim 1 consisting of 0.4% to 0.5% carbon. 20
5. The austenitic stainless steel alloy of claim 1 consisting of 0.3% to 0.5% nitrogen.
6. A turbocharger turbine housing comprising: 25
 an austenitic stainless steel alloy, wherein the austenitic stainless steel alloy consists of, by weight:
 24% to 26% chromium; 30
 3.5% to 6.5% nickel;
 1.0% to 6.0% manganese;
 1.0% to 2.0% silicon;
 0.3% to 0.6% carbon;
 0.2% to 0.5% nitrogen; 35
 0.03% sulfur or less;
 0.03% phosphorous or less;
 optionally, one or more of boron, calcium, and cerium, each, if provided, in an amount of 0.005% or less; and 40
 a balance of iron and inevitable/unavoidable impurities, with the proviso that molybdenum, niobium, and tungsten are excluded from the alloy. 45
7. The turbocharger turbine housing of claim 6 consisting of 4.0% to 6.0% nickel.
8. The turbocharger turbine housing of claim 6 consisting of 1.5% to 5.5% manganese. 50
9. The turbocharger turbine housing of claim 6 consisting of 0.4% to 0.5% carbon.
10. The turbocharger turbine housing of claim 6 consisting of 0.3% to 0.5% nitrogen. 55
11. The use of the alloy of claim 1 to provide a turbo-

charger turbine housing according to claim 6; and
 a turbocharger turbine using the turbocharger turbine housing of claim 6.

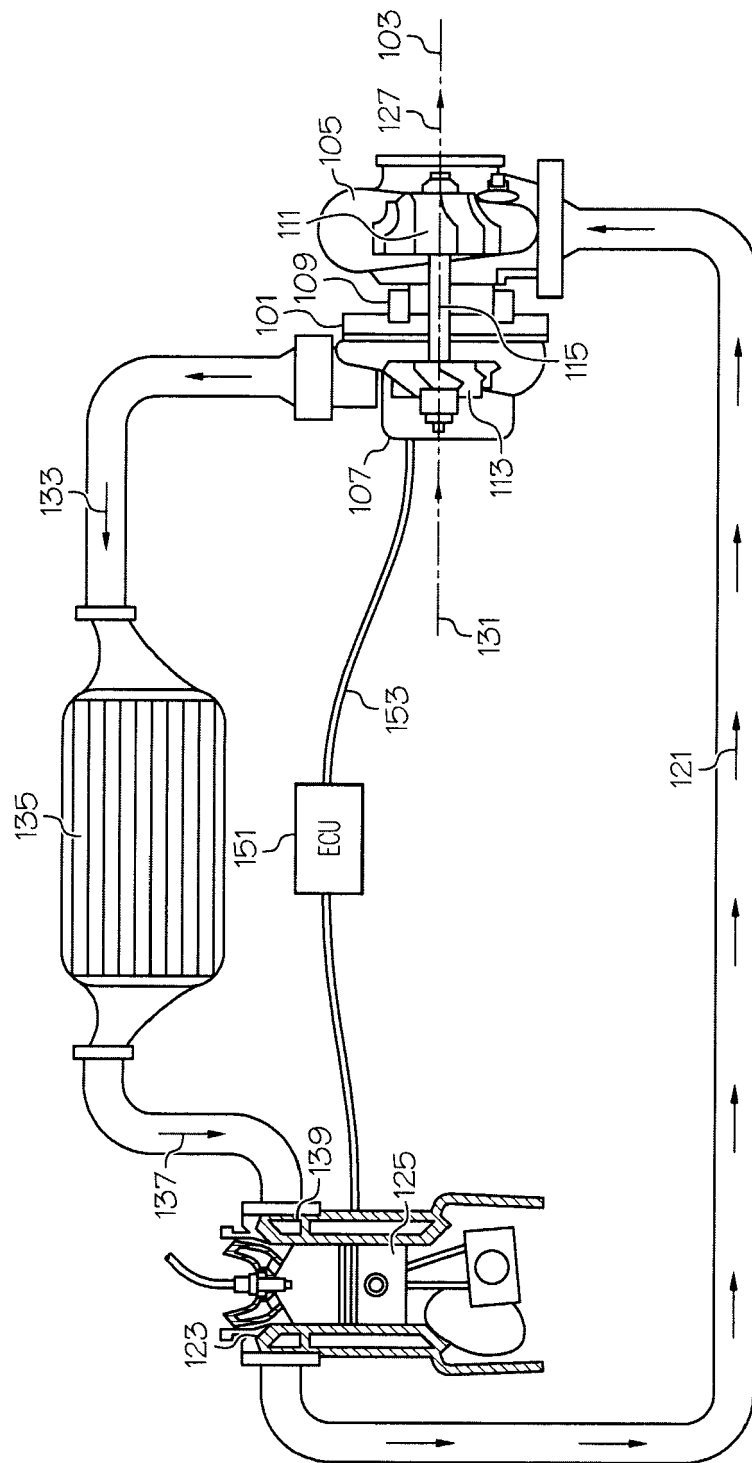


FIG. 1



EUROPEAN SEARCH REPORT

 Application Number
 EP 16 15 2144

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 3 969 109 A (TANCZYN HARRY) 13 July 1976 (1976-07-13) * claims 1-3, 7, 8 * * column 3, line 40 - column 6, line 27 * * tables I-VI *	1-15	INV. C22C38/00 C22C38/02 C22C38/34 C22C38/38 F01D25/24
X	WO 2011/124970 A1 (TOYOTA MOTOR CO LTD [JP]; AISIN TAKAOKA LTD [JP]; GENMA YOSHIKAZU [JP]) 13 October 2011 (2011-10-13) * claim 1 * * paragraphs [0001], [0002] * * tables 2, 7 * * paragraphs [0015] - [0036] *	1-15	
X	US 2 686 116 A (REINHOLD SCHEMPP ET AL) 10 August 1954 (1954-08-10) * tables II,V * * column 1, line 1 - column 2, line 15 * * claims 1-11 *	1,3,4,6,8,10,11,13,15 2,5,7,9,12,14	TECHNICAL FIELDS SEARCHED (IPC)
X	US 2 799 577 A (REINHOLD SCHEMPP ET AL) 16 July 1957 (1957-07-16) * claims 1-2 * * column 1, line 1 - column 2, line 13 *	1,3,4,6,8,10,11,13,15 2,5,7,9,12,14	C22C F01D
X	US 2 826 496 A (KEGERISE WESLEY R) 11 March 1958 (1958-03-11) * claims 1-11 * * table II * * column 1, line 1 - column 4, line 61 *	1,3,4,7,8,10,11,14,15 2,5,6,9,12,13	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 12 July 2016	Examiner Vlassi, Eleni
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			



EUROPEAN SEARCH REPORT

Application Number
EP 16 15 2144

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 3 549 426 A (KWAKE RICHARD A ET AL) 22 December 1970 (1970-12-22) * claims 1-3 * * tables I-III * -----	1-15	
A	GB 1 202 730 A (REPUBLIC STEEL CORP [US]) 19 August 1970 (1970-08-19) * claims 1-12 * * tables I-II *	1-15	
A	US 3 607 461 A (STANLEY DELMAR O ET AL) 21 September 1971 (1971-09-21) * claims 1-2 * * table I *	1-15	
A	JP H09 287022 A (DAIDO STEEL CO LTD) 4 November 1997 (1997-11-04) * the whole document *	1-15	
A	US 2 891 858 A (KEGERISE WESLEY R ET AL) 23 June 1959 (1959-06-23) * claims 1-5 * * tables I, V *	1-15	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
Place of search		Date of completion of the search	Examiner
The Hague		12 July 2016	Vlassi, Eleni
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 15 2144

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

12-07-2016

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15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3969109 A	13-07-1976	AU 8339675 A	27-01-1977
		BR 7505098 A	03-08-1976
		CA 1070528 A	29-01-1980
		DE 2535516 A1	04-03-1976
		ES 440167 A1	01-03-1977
		FR 2281994 A1	12-03-1976
		GB 1514184 A	14-06-1978
		IT 1041170 B	10-01-1980
		JP S5144505 A	16-04-1976
		JP S5732711 B2	13-07-1982
		RO 71801 A	30-08-1981
		SE 425858 B	15-11-1982
		US 3969109 A	13-07-1976
WO 2011124970 A1	13-10-2011	YU 201675 A	21-01-1983
		ZA 7504798 B	30-06-1976
		CN 102844455 A	26-12-2012
		EP 2556177 A1	13-02-2013
		JP 5227359 B2	03-07-2013
		JP 2011219801 A	04-11-2011
US 2686116 A	10-08-1954	US 2013022488 A1	24-01-2013
		WO 2011124970 A1	13-10-2011
US 2799577 A	16-07-1957	NONE	
US 2826496 A	11-03-1958	NONE	
US 3549426 A	22-12-1970	NONE	
GB 1202730 A	19-08-1970	BE 708930 A	03-07-1968
		DE 1608199 B1	20-07-1972
		FR 1568005 A	23-05-1969
		GB 1202730 A	19-08-1970
		NL 6800152 A	08-07-1968
US 3607461 A	21-09-1971	NONE	
JP H09287022 A	04-11-1997	JP 3721637 B2	30-11-2005
		JP H09287022 A	04-11-1997
US 2891858 A	23-06-1959	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82