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## Patent Public Search | Text View

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United States Patent Application Publication

20250257435

Kind Code

A1

Publication Date

August 14, 2025

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### MOLYBDENUM-Based Alloy

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#### Abstract

Disclosed is an alloy based on molybdenum for industrial applications. The alloy exhibits minimal wear and good corrosion resistance in a high temperature range and can also be used in the event of poor lubrication of the components. The advantageous characteristics of the molybdenum-based alloy are based on the metallurgical structure with Laves phases and a novel material composition. The processing of the alloy can take place by various methods, such as casting, forging, sintering, welding or metal spraying and for producing components or also coatings.

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**Family ID:** 1000008612755

**Appl. No.:** 18/617521

**Filed:** March 26, 2024

#### Foreign Application Priority Data

DE 10 2023 108 051.2

Mar. 29, 2023

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#### Publication Classification

**Int. Cl.:** C22C30/00 (20060101); C22C1/02 (20060101)

**U.S. Cl.:**

**CPC** C22C30/00 (20130101); C22C1/02 (20130101)

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#### Background/Summary

## BACKGROUND OF THE INVENTION

[0001] The present invention relates to an alloy based on molybdenum for industrial applications. It is characterised in particular by minimal wear and good corrosion resistance in a high temperature range and can also be used in the event of poor lubrication of components. The advantageous characteristics of the molybdenum-based alloy are based on the metallurgical structure with Laves phases and a novel material composition. The processing of the alloy can take place by various methods, such as casting, forging, sintering, welding or metal spraying and for producing components or also coatings.

[0002] New technological challenges necessitate materials which are specially tailored to the purpose for which they are to be used. Not only the loading of the material by forces acting on it, but also the thermal stress increases continuously with the further development of machines. In addition, corrosive characteristics of the media and consumables or also the absence or reduction of media which could contribute to the cooling and/or lubrication of the components. By way of example mention may be made here of the use of valve seat inserts in gas-powered supercharged internal combustion engines. Due to the ever higher specific output, there is an increase in the thermal stress on the valve seat inserts and the heat flux which must be discharged via the valve seat inserts with the valves closed. In addition there is also a corrosive action of the gas mixture which the valve seat inserts must withstand over the lifetime of the unit.

[0003] Metal alloys having good corrosion and wear characteristics are known for example under the designation Tribaloy™. These alloys are cobalt-based and have a hard and wear-resistant structure which is achieved with the aid of Laves phases.

## SUMMARY OF THE INVENTION

[0004] The object of the present invention is to further improve the metallic characteristics in a high temperature range from approximately 700° C. to 800° C. and at the same time to use an alloy composition which can be produced in a manner which conserves resources and is cost-effective. In this case the alloy composition should be designed in such a way that it can be used for the most varied applications. This presupposes different forms of processing, such as casting, forging, sintering or spraying. Characteristics of the alloy which in this case are to be intentionally improved are the wear resistance, that is to say a minimal removal/abrasion of material, and the corrosion resistance, that is to say the material remaining in its production state without any further chemical conversion process, such as oxidation, which would lead to a deterioration of the material characteristics. For use in the event of poor or absent outer lubrication, in addition to minimal wear and the accompanying high degree of hardness, a low coefficient of friction for the components which are in contact is also necessary.

[0005] Wear-resistant and temperature-resistant alloys based on cobalt, such as the alloys Tribaloy™ T-400 and T800, reflect the current state of the art. In contrast to this, the present invention is based on molybdenum. In this case the element which has the highest proportion by weight of the alloy is designated as base material.

[0006] Molybdenum (Mo) preferably forms the foundation stone for production of the hard and resilient Laves phases. These Mo-based Laves phases provide a thermal stability of up to 1230° C.

[0007] Laves phases are topologically densely packed intermetallic compounds with a hexagonal C14 or C36 structure or with a cubic C15 structure. In order to be able to form Laves phases, the metals must have a specific ratio of the atom radii. Only then can they be arranged in the particularly dense packing in which the atoms of the metals fill the gaps particularly efficiently. The present alloy preferably has hexagonal C14 and C36 structures.

[0008] If the proportion of molybdenum in the alloy is insufficient, the required hardness is not achieved. On the other hand, if it is too high an embrittlement of the alloy can occur; undesirable material characteristics are the consequence. By comparison with the prior art the proportion of cobalt (Co) can be reduced and the proportion of the element molybdenum can be increased by the

novel molybdenum base. In this way not only is the rare cobalt resource conserved, which makes the alloy more sustainable relative to the prior art, but also the cost-effectiveness is increased by the more economical molybdenum as alloy base. Moreover, molybdenum improves the high-temperature performance and forms a strong bond with cobalt which increases the strength of the alloy and improves the resistance to deformation thereof at high temperatures. The alloy element molybdenum is therefore present in the metallic structure in a range from 10% by weight to 60% by weight, advantageously in a range from 22% by weight to 38% by weight, and particularly advantageously in a range from 26% by weight to 28% by weight.

[0009] Chromium (Cr) is generally used in alloys in order to minimise the susceptibility to corrosion. Also in the present invention this element is used for the required corrosivity, as it forms a passive oxide coating on the surface of the alloy which protects it against further corrosion. At Cr contents below 10% by weight the alloy tends towards corrosion and does not meet the set requirements. Cr contents which are too high at over 30% by weight generally lead to an embrittlement of the material and thus to an unsatisfactory material.

[0010] An optimal chromium content in the alloy enables the distribution of the element Cr with for instance 55% to 65%, preferably 60%, in the Laves phase and with for instance 35% to 45%, preferably 40%, in the matrix and thus improves the resistance to oxidation of the entire alloy up to 1230° C., and a chromium oxide passivation layer is formed instead of a thicker Co—Mo—Cr oxide layer, as is the case with alloys which correspond to the current state of the art.

[0011] The alloy element chromium is therefore present in the metallic structure in a range from 10% by weight to 30% by weight, advantageously in a range from 13% by weight to 17% by weight, and particularly advantageously in a range from 14% by weight to 16% by weight.

[0012] Unless stated otherwise, all percentage information given in connection with this invention should be understood as percentages by weight (% by weight), relative to the total mass of the alloy.

[0013] Furthermore it is pointed out that the above-mentioned preferred proportions by weight, just like the preferred proportions by weight mentioned below for the further constituents of the alloy, can in each case be selected independently of one another. Thus for example it is conceivable that a proportion of Cr lies within a range mentioned as preferred, but a proportion of Fe for example lies in a range which is not described as preferred, but is selected from a further range. This also applies analogously with respect to the ranges which are mentioned as particularly preferred, which can likewise be selected for each constituent of the alloy irrespective of whether the proportion of other constituents is selected within a range disclosed as particularly preferred.

[0014] A proportion of silicon (Si) in the alloy can improve the material characteristics. The ratio of silicon to the further elements which form the Laves phase is adapted in this case. The proportion by weight of silicon is up to 5.0% by weight, in a preferred embodiment 1.5% by weight to 4.5% by weight, and in a particularly preferred form the proportion by weight is 2.5% by weight to 3.5% by weight.

[0015] In order to achieve a hypereutectic alloy, the ratio by weight of the elements Mo to Si in this alloy is between 5 and 14, preferably between 6 and 13 and particularly preferably between 7.5 and 11.5.

[0016] Iron (Fe) is a favourable and frequently occurring element from the perspective of the costs and the conservation of resources. Thus the highest possible proportion of the alloy is desirable. Moreover, it can be used for setting the required material characteristics, since by comparison with other elements of the alloy it constitutes a ductile, quite reactive metal, which at a specific dosage reduces the susceptibility of the alloy to cracking and so improves the processability. An upper limit of the proportion by weight of the alloy is delimited by the tendency to corrosion and the optimal formation of Laves phases. Fe is present in the alloy in a range from 10% by weight to 30% by weight, advantageously in a range from 13% by weight to 17% by weight, and particularly advantageously in a range from 14% by weight to 16% by weight.

[0017] Cobalt (Co) is used primarily for increasing the work hardening rate, that is to say the ability to absorb stresses. This is accompanied by an increase in the resistance to wear and to corrosion. If the proportion of cobalt is too small, the required microstructure is not achieved. On the other hand an excessively high proportion of cobalt leads to an embrittlement of the material. The proportion of Co in the alloy is between 10% by weight and 40% by weight, in a preferred embodiment between 17% by weight and 23% by weight and in a particularly preferred form the proportion by weight is between 18% by weight and 22% by weight.

[0018] Also the specific use of nickel (Ni) leads to a structural improvement of the structure and thus to an improved ductility. It is used in order to increase the resistance to high temperature and corrosion, since it forms a protective oxide layer on the surface. In terms of proportions, the proportion by weight is between 10% by weight and 40% by weight, in a preferred embodiment between 17% by weight and 23% by weight and in a particularly preferred form the proportion by weight is between 18% by weight and 22% by weight.

[0019] Manganese (Mn) is likewise a constituent of the alloy. It is primarily used for improved further processing. Small proportions of manganese improve the forgeability and weldability, so that a large field of application is opened up. The proportion of manganese is up to 2% by weight of the alloy, preferably up to 0.8% by weight and particularly preferably up to 0.7% by weight.

[0020] The hardness generally increases with the content of carbon (C), although an alloy with a high carbon content tends to embrittlement, and also the weldability decreases. The proportion of carbon in the alloy is up to 2% by weight. The proportion by weight in the alloy is preferably up to 0.15% by weight and particularly preferably up to 0.1% by weight.

[0021] Further constituents of the alloy may be contaminants, trace elements, grain refiners and/or rare earths. The proportion by weight may be up to 4% by weight, preferably 3% by weight and particularly preferably 2.2% by weight.

[0022] These further constituents are not necessary in order to obtain the described alloy characteristics. However, they are unavoidable in an alloy because of the raw materials and base materials used. In fact, a high proportion of further constituents with material characteristics which are still adequate give the alloy great robustness in practical application.

[0023] Also phosphorus (P) and sulfur (S) can be present in the alloy in proportions by weight of in each case up to 0.1% by weight, preferably in each case 0.06% by weight, particularly preferably in each case 0.03% by weight. On the one hand sulfur can enter the alloy as a contaminant of the base materials, and on the other hand it can also be used in small quantities in order to increase the machinability of the alloy, although this is accompanied by a reduction in the ductility, that is to say the plastic deformation under loading. Likewise phosphorus can enter the alloy due to contamination. Small quantities of phosphorus do not adversely affect the alloy characteristics.

[0024] Trace elements, such as for example titanium (Ti), tantalum (Ta) and hafnium (Hf) can likewise be present in the alloy due to the contamination of the raw materials, without negatively influencing the material characteristics. However, an excessively large proportion may lead to greater carbide formation and may weaken the effectiveness of the intermetallic Laves phases. The proportion of the aforementioned trace elements and also other trace elements in the alloy should therefore in each case be less than 0.4% by weight, advantageously in each case less than 0.2% by weight, and particularly advantageously less than 0.1% by weight.

[0025] The total proportion of trace elements such as for example titanium (Ti), tantalum (Ta) and hafnium (Hf) in the alloy can be up to 2% by weight, preferably up to 1.5% by weight, particularly preferably up to 1% by weight, without negatively influencing the material characteristics; the wear resistance and the corrosion resistance are maintained at high temperatures. Thus the alloy exhibits great robustness in its production and further processing.

[0026] Aluminium (Al) can be added as deoxidising agent in order to react with the gases in the melt. The introduction can take place together with the slag removal powder. In order not to restrict the castability in air, the proportion of Al is up to 0.75% by weight of the alloy, preferably up to

0.5% by weight and particularly preferably up to 0.25% by weight.

[0027] In an advantageous embodiment boron (B) is used for boosting the high-temperature characteristic and breaking strength. Likewise B can act as grain refiner for the Co—Cr—Mo—Ni systems. Nevertheless, the content should be limited to a maximum of 0.3% by weight, preferably 0.2% by weight and particularly preferably 0.1% by weight, in order to minimise the formation of Ni—Cr borides and not to adversely affect the workability of the alloy.

[0028] The carbides and the intermetallic phases (Laves phase) influence the tribological characteristics. Alloys of which the characteristics are based more on Laves phases than on those of carbides have a higher thermal stability, since carbides run through a plurality of metallurgical changes which can adversely affect the thermal stability of the alloy at high temperatures.

[0029] The production of a structure with distinct Mo-based Laves phases and also the increase in the proportion of Laves phases in the alloy, compared with the prior art, lead to improved oxidation and wear characteristics. The proportion of Laves phases in the alloy is from 50 to 85% by volume, in a preferred embodiment from 60 to 80% by volume and in a particularly preferred embodiment from 65 to 75% by volume.

[0030] The alloy retains the thermal stability up to high temperatures of 1230° C. This enables the use of the alloy in machines and plants under extreme conditions and opens up the use of novel, cost-efficient applications and methods which are optimised for efficiency and in particular are also environmentally friendly and sustainable. In addition to the use in gas engines, mention may also be made here of the operation of motors with synthetic fuels which can have an aggressively corrosive action on the material; also biogas, methanol or also hydrogen as possible energy source. Also the use of ammonia for exhaust gas aftertreatment of internal combustion engines with modern leaner combustion processes requires a corresponding alloy.

[0031] Also in the case of the design of machines and motors optimised for friction the novel alloy can contribute to increasing efficiency. The highly wear-resistant alloy which is optimised for friction can be used, for instance, for bearing shells or also as a coating of bearing shells. In the interactions with new, possibly highly viscous and oils which are optimised for friction, bearing points can be optimised with regard to friction without this having a negative effect on wear and duration of operation.

[0032] The alloy is characterised by a high degree of hardness. In this case the measurement of the Rockwell hardness is a commonly used testing method, in which the penetration depth of a test piece into a material is tested. The hardness of the alloy is between 42 and 54 HRC, preferably between 45 and 52 HRC, particularly preferably between 47 and 49 HRC.

[0033] Moreover, the alloy is characterised by a low coefficient of friction. The coefficient of friction  $\mu$  of the alloy, determined with a ball on disc tribometer is between 0.06 and 0.30, particularly preferably between 0.100 and 0.150 and particularly preferably between 0.110 and 0.130.

[0034] The corrosion resistance is defined by a decrease in mass over a defined period of time in a specific test medium. Over a time period of 2000 hours in potassium nitrate (KNO<sub>3</sub>) at 720° C. +/- 30° C., in the case of this novel alloy for example there is a reduction of up to 0.3% by mass, preferably 0.2% by mass and particularly preferably 0.1% by mass.

[0035] The resistance to oxidation is determined at a defined high temperature. In the case of storage for 4 hours at 1200° C. the layer thickness of the oxides is preferably 50 to 400  $\mu\text{m}$ , preferably 75 to 300  $\mu\text{m}$  and particularly preferably 100 to 150  $\mu\text{m}$ .

[0036] The resistance to oxidation of alloys according to the prior art under the said conditions of storage for 4 hours at 1200° C. shows a substantially higher layer thickness of the oxides of 1.0 to 1.5 mm.

[0037] The alloy can be used for all known manufacturing processes. These include primary shaping, reshaping, joining, coating and cutting. Furthermore, heat treatments can be carried out in order to further optimise the material characteristics.

[0038] In an advantageous embodiment the alloy can be heated and reshaped with forging tools. All types of open die forging and closed die forging are possible, as are deep drawing, bending or rolling.

[0039] In another advantageous embodiment the alloy is heated and melted and the liquid melt is poured into a mould in which it is then solidified. Both the precise casting method and also the casting mould can be optimised for the respective application. All types of casting such as mould casting, pressure die casting, ingot casting and continuous casting, investment casting, resin shell casting and centrifugal casting are possible types of application. In this case the melting range of the alloy is between 1050° C. and 1450° C., preferably between 1100° C. and 1400° C. and particularly preferably between 1170° C. and 1350° C.

[0040] In a further advantageous embodiment the alloy has, in addition to the high temperature resistance and the wear resistance, a reduced density of up to 10% by comparison with the prior art, which is achieved primarily by a reduction of the cobalt proportion of the alloy and the novel composition. Especially for movable components which are subject to rotational and/or translational movements, this leads not only to a lower weight, but also to lesser forces which act on the component. This is a positive effect, especially for example for turbine blades. The density of the alloy is between 7 g/cm.sub.3 and 9 g/cm.sub.3, preferably between 7.5 g/cm.sub.3 and 8.5 g/cm.sub.3 and particularly preferably between 7.8 g/cm.sub.3 and 8.2 g/cm.sub.3.

[0041] The alloy can be melted in air or in the presence of argon as protective gas atmosphere. Moreover, the composition of the alloy is optimised in order to avoid or at least to significantly reduce an embrittlement of the alloy and casting cracks and consequently to facilitate the reject rate and the further processing of the alloy.

[0042] In a further advantageous embodiment workpieces of the alloy can be joined by welding. In this case it is possible that all components and any additional material present consist of the same alloy. In another embodiment two components of different alloys can be joined together by welding. In this case any additional material used can consist of one of the two materials to be joined, or of a third material of a different alloy composition. The friction welding of, for example, valves is a further possible type of application.

[0043] In a further embodiment the alloy can be processed in the form of welded rods, wires and electrodes for the gas-shielded welding. In this case the embodiments of inert gas welding and active gas welding are conceivable. The base material can consist of the same material as the additional material, that is to say the welding rod, or can also have a different alloy composition.

[0044] In a further embodiment of the joining, components of the alloy can be soldered. In this case both or also only one component which are joined can be produced from the alloy. Naturally, adhesion of components of the alloy is likewise possible.

[0045] In an advantageous embodiment a component of the alloy can be further processed by cutting. In spite of the hard and resilient alloy, production in several steps is possible, so that a blank is further processed by further machining operations, such as for instance drilling, milling or sawing to produce a precisely made, dimensionally stable end product. By way of example, mention may be made here of the embodiment of a cylinder head, cast in a die-casting process, with milled flat surfaces, bearing seats and drilled thread pitch turns.

[0046] Likewise, in a further embodiment it is possible to fabricate semi-finished products which can be further processed for individual applications,

[0047] In a further embodiment a component produced from the present alloy is coated. Likewise it is possible for components produced from other materials to be coated with the present alloy. In this case various methods can be used. Amongst other things the alloy can be applied by thermal spraying or also by laser build-up welding on surfaces of the most varied components.

[0048] In an advantageous embodiment the alloy can be used as a powder for sintering components and workpieces. The alloy powder is consolidated by pressing. The material is brought into its ultimate form by a subsequent heat treatment.

[0049] In a further advantageous embodiment the alloy can be used as a powder for metal spraying. In this case the alloy powder is sprayed with high kinetic and thermal energy onto a workpiece prepared therefor.

[0050] In a further advantageous embodiment the alloy can be processed to a powder for plasma transfer arc welding, laser deposition welding, plasma spraying and/or high-speed flame spraying. The particle size of the powder can be adapted to the respective method. Likewise, the alloy powder within the said boundaries can be tailored to the base material to be welded.

[0051] For the respective application the alloy can be varied within the said limits in order to achieve optimal characteristics for the manufacturing process and/or the workpiece.

[0052] In an advantageous embodiment a heat treatment can take place after the production of a component or the application of the alloy in order to further optimise the specific characteristics, such as wear, friction and/or hardness for the respective application.

[0053] In a further advantageous embodiment, in the Laves phases half of the atom positions of Ni are occupied by Fe and Co, so that the Laves phases have a composition of  $\text{Mo—Si—Cr}+(0.25 \text{ Fe}+0.25 \text{ Co}+0.5 \text{ Ni})$ .

[0054] In an advantageous embodiment the alloy can be produced by means of a casting process, wherein firstly the furnace, for example an induction furnace, is loaded with raw material or the base materials of the alloy. In this case the raw materials or base materials correspond to the substances and the corresponding percentages by weight of the described embodiments of the alloy.

[0055] The raw material, or the base materials of the alloy, are preferably heated to a temperature of 1600° C. or higher and the temperature is maintained for example for at least 60 seconds. In an advantageous embodiment the heating time and/or the holding time can take place under an argon protective atmosphere. After this the deslagging takes place. The alloy can then be cast at a temperature >1600° C. in the case of centrifugal casting and/or sand casting.

[0056] Casting is also possible at a temperature >1500° C. in the case of investment casting and/or resin shell casting. In this case the shell temperature in investment casting is preferably between 700 and 1200° C., more preferably between 850 and 1050° C. The shell is not heated in advance in the case of resin shell casting, centrifugal casting and/or sand casting.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0057] FIG. 1: Micrograph of a metallographic structure according to the present invention with a molybdenum-based alloy.

[0058] FIG. 2: Micrograph of a metallographic structure of the Tribaloy™ T800 with a cobalt-based alloy.

### DETAILED DESCRIPTION OF THE INVENTION

[0059] FIG. 1 shows the micrograph of a sample of a preferred embodiment of the present invention. The scale 1 was chosen to be 10 µm. The metallic structure in the novel alloy is primarily characterised by two phases. In this case the greatest space is occupied by the homogeneous Mo-based Laves phases 2 with dendrites. These dendrites are to some extent widely branched and have not only primary, but also secondary and tertiary structures. These are embedded in a second phase 3, the matrix.

[0060] FIG. 2 shows the micrograph of a sample of the prior art Tribaloy™ T800. By comparison with the novel alloy, at the same scale 1 of 10 µm the structure is substantially coarser. The Co-based Laves phases 4 usually have no dendrites, or only primary dendrites. Moreover, due to the coarser structure of the Laves phases 4 the area of the second phase 5 is greater.

List of Reference Numerals

## Claims

1. A Mo-based metallic Ni—Co—Cr—Fe—Mo alloy for the production of components, coatings and substrates, which in a high temperature range exhibits characteristics of low wear, corrosion resistance, oxidation resistance and minimised friction, wherein the metallic composition contains: Mo between 10% by weight and 60% by weight, Cr between 10% by weight and 30% by weight, Si between 0.5% by weight and 5.0% by weight, Fe between 10% by weight and 30% by weight, Co between 10% by weight and 40% by weight, Ni between 10% by weight and 40% by weight, Mn up to 2.0% by weight, Mn up to 2.0% by weight, and further constituents up to 4% by weight.
2. The metallic alloy according to claim 1, wherein the metallic composition contains an individual element, a plurality of or all of the elements mentioned below in the respectively stated range of proportion by weight: Mo between 22% by weight and 38% by weight, Cr between 13% by weight and 17% by weight, Si between 1.5% by weight and 4.5% by weight, Fe between 13% by weight and 17% by weight, Co between 17% by weight and 23% by weight, Ni between 17% by weight and 23% by weight, Mn up to 0.8% by weight, C up to 1.40% by weight, and further constituents up to 3% by weight.
3. The metallic alloy according to claim 1, wherein the metallic composition contains an individual element, a plurality of or all of the elements mentioned below in the respectively stated range of proportion by weight: Mo between 26% by weight and 28% by weight, Cr between 14% by weight and 16% by weight, Si between 2.5% by weight and 3.5% by weight, Fe between 14% by weight and 16% by weight, Co between 18% by weight and 22% by weight, Ni between 18% by weight and 22% by weight, Mn up to 0.7% by weight, C up to 0.1% by weight, and further constituents up to 2.2% by weight.
4. The metallic alloy according to claim 1, wherein a ratio of Mo to Si is selected from the group consisting of between 5 and 14, between 6 and 13, and between 7.5 and 11.5.
5. The metallic alloy according to claim 1, wherein the proportion of P and S in the alloy is in each case selected from the group consisting of up to 0.1% by weight, up to 0.06% by weight, and up to 0.03% by weight.
6. The metallic alloy according to claim 1, wherein the proportion of Ti, Ta, Hf and other trace elements in the alloy is in each case selected from the group consisting of up to 0.4% by weight, up to 0.2% by weight, and up to 0.1% by weight, and/or the total proportion of Ti, Ta, Hf and other trace elements in the alloy is selected from the group consisting of up to 2% by weight, up to 1.5% by weight, and up to 1% by weight.
7. The metallic alloy according to claim 1, wherein the proportion of Al in the alloy is selected from the group consisting of up to 0.75% by weight, up to 0.5% by weight, and up to 0.25% by weight.
8. The metallic alloy according to claim 1, wherein the proportion of B in the alloy is selected from the group consisting of up to 0.3% by weight, up to 0.2% by weight, and up to 0.1% by weight.
9. The metallic alloy according to claim 1, wherein the melting range is selected from the group consisting of from 1050 to 1450° C., from 1100 to 1400° C., and from 1170 to 1350° C.
10. The metallic alloy according to claim 1, wherein the proportion of Laves phases in the alloy is selected from the group consisting of from 50 to 85% by volume, from 60 to 80% by volume, and from 65 to 75% by volume.
11. The metallic alloy according to claim 1, wherein the hardness is selected from the group consisting of between 42 and 54 HRC, between 45 and 52 HRC, and between 47 and 49 HRC.
12. The metallic alloy according to claim 1, wherein the coefficient of friction  $\mu$  of the alloy, measured with a ball on disc tribometer, is selected from the group consisting of between 0.06 and



0.30, between 0.100 and 0.150, and between 0.110 and 0.130.

**13.** The metallic alloy according to claim 1, wherein the density is selected from the group consisting of between 7 g/cm.<sup>3</sup> and 9 g/cm.<sup>3</sup>, between 7.5 g/cm.<sup>3</sup> and 8.5 g/cm.<sup>3</sup>, and between 7.8 g/cm.<sup>3</sup> and 8.2 g/cm.<sup>3</sup>.

**14.** The metallic alloy according to claim 10, wherein the proportion of Laves phases, the hardness, the coefficient of friction and/or the density is achieved by a casting production process without further heat treatment.

**15.** The metallic alloy according to claim 11, wherein the proportion of Laves phases, the hardness, the coefficient of friction and/or the density is achieved by a casting production process without further heat treatment.

**16.** The metallic alloy according to claim 12, wherein the proportion of Laves phases, the hardness, the coefficient of friction and/or the density is achieved by a casting production process without further heat treatment.

**17.** The metallic alloy according to claim 13, wherein the proportion of Laves phases, the hardness, the coefficient of friction and/or the density is achieved by a casting production process without further heat treatment.

**18.** A method for producing an alloy, comprising the following steps: a) supplying raw material/base materials to a furnace, wherein the raw materials/base materials contain at least the elements with the corresponding percentages by weight of the total weight of the alloy according to claim 1, and b) heating of the raw material to a temperature of 1600° C. or higher.

**19.** The method for producing an alloy according to claim 18, which optionally contains one or more of the following additional steps: c) holding time for the temperature of at least 60 seconds, d) deslagging, e I) casting at a temperature > 1600° C. in the case of centrifugal casting and/or sand casting, and e II) casting at temperature > 1500° C. in investment casting and/or resin shell casting, wherein the shell temperature in investment casting is selected from the group consisting of between 700 and 1200° C., and between 850 and 1050° C., and wherein the shell is not heated in advance in the case of resin shell casting, centrifugal casting and/or sand casting.

**20.** The method according to claim 18, wherein the step b) takes place in an atmosphere of argon (Ar).

**21.** The method according to claim 19, wherein step c) takes place in an atmosphere of argon (Ar).

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