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[Continued on next page]

(54) Title: SEAL RINGS COMPRISING CHROMIUM AND BORON CAST IRON

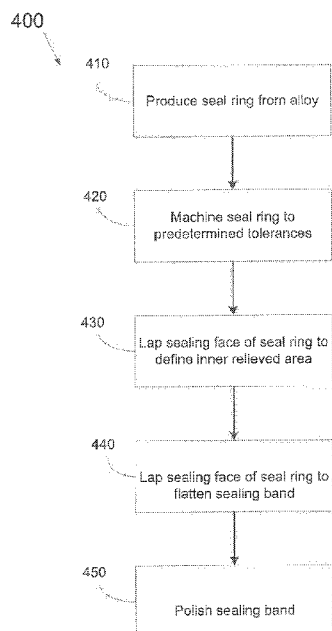


FIG.4

(57) Abstract: A seal ring (100) comprising a chromium and boron containing cast iron alloy composition is disclosed. The cast iron alloy composition comprises each of boron, chromium and silicon in the following amounts: boron up to 1.5 wt. %; chromium from 8 to 14 wt. %; and silicon up to 3.0 wt. %. The seal ring (100) may be produced by melting a cast iron composition further comprising the foregoing alloying elements; pouring the melted alloy into a mold; cooling the melted alloy to form a cast iron seal ring; and separating the cast iron seal ring from the mold. The seal ring is typically used in the undercarriage of earth-working machines, such as in the drive train or power train of such machines.

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SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, **Published:**

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— *with international search report (Art. 21(3))*

Description

SEAL RINGS COMPRISING CHROMIUM AND BORON CAST IRON

Technical Field

5 The present disclosure relates generally to seal rings, and more particularly to seal rings comprising chromium and boron containing cast iron that have enhanced performance characteristics, including improved wear and corrosion resistance.

Background

10 Many earth-working machines, such as loaders, tractors, and excavators, operate in extremely adverse environments often exposing the undercarriage components to various abrasive mixtures of water, dirt, sand, rock or chemical elements. Current undercarriage seal rings do not meet the targets for life in lower powertrain applications for mining and quarry products.

One attempt to produce cast seal rings that have increased
15 performance is described in published U.S. Patent Application No. U.S. 2012/0058710 to Young Jin Ma (“the ’710 application”) that published on March 8, 2012. The ’710 application discloses a centrifugal casting method that produces a unique alloy microstructure over a traditional shell mold casting method, even if the same alloy cast iron is used. The centrifugal casting method
20 described in the ’710 application is not feasible because it requires large amounts of expensive alloying elements to achieve a desired microstructure, including increased amounts of nickel (Ni) for stabilizing an austenite phase, and molybdenum (Mo) for suppressing a martensite phase and unwanted carbides.

U.S. Patent No. 3,758,296 (“the ’296 patent”) to Thomas E.
25 Johnson describes another example of a corrosion-resistant cast alloy that requires the use of expensive alloying elements, including: 26-48 wt. % of Ni; 30-34 wt. % Cr; and 4.0-5.25 wt. % Mo. While such an alloy does achieve increased corrosion resistance, the cost associated with using these alloying elements makes the use of this alloy prohibitive in most commercial
30 applications.

The disclosed seal ring comprising chromium and boron cast iron is directed to overcoming one or more of the problems set forth above and/or other problems of the prior art.

Summary

5 In one aspect, the present disclosure is directed to a seal ring including a cast iron composition. The cast iron composition includes B, Cr, and Si in the following amounts: B in an amount up to 1.5 wt. %; Cr in an amount ranging from 8.0 to 14.0 wt. %; and Si in an amount up to 3.0 wt. %.

10 In a further aspect, the present disclosure is directed to a method of making a cast iron seal ring. The method may include melting an alloy composition comprising B, Cr, and Si in the following amounts: B in an amount up to 1.5 wt. %; Cr in an amount ranging from 8.0 to 14.0 wt. %; and Si in an amount up to 3.0 wt. %; pouring the melted alloy into a mold; cooling the melted alloy to form a cast iron seal ring; separating the cast iron seal ring from the
15 mold; and machining the seal ring to at least one predetermined tolerance.

 In yet another aspect, the present disclosure is directed to an undercarriage seal ring. The undercarriage seal ring may include a body that is generally cylindrical and extending along a longitudinal axis between a load end and a seal end; a seal flange, the seal flange disposed at the seal end of the body,
20 the seal flange circumscribing the body and projecting radially from the body to a distal perimeter of the seal flange, the seal flange including a sealing face, the sealing face being annular and disposed adjacent the distal perimeter, wherein the seal ring is made from a cast iron composition, comprising: C: 2.8 to 3.6 wt. %; Mn: 0.40 to 1.0 wt. %; Ni: 3.0 to 5.0 wt. %; V: up to 1.0 wt. %; Mo: up to
25 0.80 wt. %; B: greater than 0 and up to 1.5 wt. %; Cr: from 8.0 to 14.0 wt. %; Si: greater than 0 and up to 3.0 wt. %; P: up to 0.08 wt. %; S: up to 0.2 wt. %; and the balance comprising Fe and incidental impurities. In an embodiment, the cast iron composition has a microstructure comprising more than 50 wt. % of martensite, austenite, and combinations thereof.

30 Brief Description of the Drawings

 FIG. 1 is an axial end view of a seal ring according to the present disclosure.

FIG. 2 is an enlarged, fragmentary view of the seal ring of FIG. 1 corresponding to the location encompassed by circle VI in FIG. 1.

FIG. 3 is an enlarged, cross-sectional view taken along line VII—VII in FIG. 1.

5 FIG. 4 is a flow chart illustrating steps of an embodiment of a method of making a seal ring as described herein.

Detailed Description

There are disclosed embodiments of boron containing cast iron compositions for seal rings with enhanced performance characteristics, and
10 methods of making such seal rings. In an embodiment, there is disclosed a boron containing cast iron composition comprising each of boron (B), chromium (Cr), and silicon (Si) in the following amounts: B up to 1.5 wt. %, such as an amount ranging from 0.5 to 1.0 wt. %; Cr in an amount ranging from 8.0 to 14 wt. %, such as an amount ranging from 10 to 14 wt. %; and Si in an amount up
15 to 3.0 wt. %, such as an amount ranging from 1.5 to 2.4 wt. %.

In an embodiment, the alloy also includes carbon (C) in an amount ranging from 2.8 to 3.6 wt. %; manganese (Mn) in an amount ranging from 0.40 to 1.0 wt. %; nickel (Ni) in an amount ranging from 3.0 to 5.0 wt. %; vanadium (V) in an amount up to 1.0 wt. %; molybdenum (Mo) in an amount up
20 to 0.80 wt. %; phosphor (P) in an amount up to 0.08 wt. %; sulfur (S) in an amount up to 0.2 wt. %, with the balance comprising iron (Fe) and incidental impurities.

In an embodiment, the cast iron composition has a microstructure comprising less than 50 wt. % carbide, such as between 5 to 45 wt. % carbide, or
25 10 to 40 wt. % carbide, or even 15 to 35 wt. % carbide, or any combination of these ranges, such as 35 to 40 wt. % carbide.

In an embodiment, the cast iron composition has a microstructure comprising more than 50 wt. % of martensite, austenite and combinations thereof. For example, in various embodiments, the cast iron composition has a
30 microstructure comprising martensite, austenite and combinations thereof in amounts ranging from 50 to 95 wt. %, 55 to 90 wt. %, 60 to 85 wt. %, 70 to 80 wt. %, or any combination of these ranges, such as 80 to 95 wt. %. As described in more detail below, the alloy composition described herein can be heat treated

after casting to allow a majority of this phase to comprise martensite. In an embodiment, at least 75 wt. %, such as 80 to 95 wt. % of this phase comprises martensite. In another embodiment, substantially the entire phase, e.g., at least 99% of this phase is martensite.

5 In an embodiment, a seal ring can be made from an alloy described herein using any suitable method of making a seal ring, such as mold casting, sand die casting, and centrifugal casting. In embodiments, the seal ring includes a body and a seal flange. The body is generally cylindrical and extends along a longitudinal axis between a load end and a seal end. The seal flange is
10 disposed at the seal end of the cylindrical body. The seal flange circumscribes the body and projects radially from the body to a distal perimeter of the seal flange. The seal flange includes a sealing face which is annular and disposed adjacent the distal perimeter.

 A more detailed description of the body of the seal ring including
15 the steps of an embodiment of a method of making it is provided in the Figures 1-4. Referring to FIGS. 1 and 2, a seal ring 100, which is an example of an embodiment according to the present disclosure, is shown. The seal ring 100 is in the shape of an annulus. The seal flange 105 includes the sealing face 110. The sealing face 110 includes the sealing band 115 disposed adjacent the outer
20 perimeter 120 of the seal flange 105 and an inner relieved area 125 disposed between the sealing band 115 (which is shown as a hatched area in FIGS. 1 and 2 for illustrative purposes) and an inner perimeter 130 of the seal ring 100. The inner relieved area 125 can be tapered between the sealing band 115 and the
25 inner perimeter 130 such that the inner perimeter 130 is axially displaced from the sealing band 115.

 Referring to FIG. 3, the seal ring 100 includes a cylindrical body 140 and the seal flange 105. The cylindrical body 140 extends along the longitudinal axis "LA" between the load end 145 and the seal end 150, which is in opposing relationship to the load end 145. The cylindrical body 140 includes
30 the inner perimeter 130 which is substantially cylindrical and the majority of the inclined loading surface 155, which is in outer, radial spaced relationship to the inner perimeter 130.

 The seal flange 105 is disposed at the seal end 150. The seal flange 105 projects radially from the cylindrical body 140 to the outer perimeter

120 thereof. The sealing face 110 is disposed on the seal flange 105 and extends radially with respect to the longitudinal axis "LA." The sealing band 115 can be substantially flat in cross-section between an inner radial edge 135 and the outer perimeter 120 (also shown in FIG. 2). In an embodiment, the sealing band 115
 5 can include an outer relieved area disposed adjacent the outer perimeter 120 that is tapered.

Example

In the Example, seal rings comprising a chromium and boron containing alloy described herein were made and compared to seal rings made with a commercially available alloy. The compositions of the alloys are shown
 10 below in Table I. Of note are the higher amounts of chromium and boron, and lower amount of nickel in the disclosed alloy, compared to commercially available alloys.

Table I. Alloy Compositions for Testing		
Element	Commercial Alloy (wt. %)	Inventive Alloy (wt. %)
Carbon	2.90	3.30
Silicon	1.90	1.90
Manganese	0.50	0.60
Chromium	8.50	12.00
Nickel	5.50	3.80
Molybdenum	0.20	0.10
Vanadium	0.20	0.60
Phosphor	0.05	0.05
Sulfur	0.01	0.01
Boron	0.25	0.75
Iron	Balance	

The above alloys were melted in a production furnace and brought to a pour temperature of 1350° C. The melted alloy was used in a static casting process to form seal rings of the same nominal size and geometric configuration. The seal rings were machined to tolerance using production lathes with standard tool inserts and prepared for pressure velocity testing.

Next, the seal rings were tested for pressure velocity (PV). In these tests, a test fixture design was used that held the seal rings in spatial and orientation relationship as per their ordinary and intended use, including the test fixture providing a predetermined seal gap. The test fixture contained a seal cavity which was filled to a center fill line with oil at ambient temperature. The sealing faces of the contacting seal rings were subjected to an axial pressure, and one seal ring was rotated relative to the other seal ring at an initial rotational velocity. All of the seal rings were subjected to PV testing with the same load and seal gap settings.

In particular, the testing conditions comprised a faceload of 1.2 N/mm and a cavity pressure of 10.0 KPa. The PV testing, specifically the rotation of the seal ring, was conducted according to the following cycle as set forth below in Table II:

TABLE II. Cycle for PV Testing	
Point of Cycle	Rotational Speed and Time
1 (Start)	0 rpm
1-2	Accelerate to 50 rpm at 40 rpm/sec
2-3	Forward Time, 240 sec at 50 rpm
3-4	Decelerate to 0 rpm at -40 rpm/sec
4-5	Dwell Time, 60 sec at 0 rpm
5-6	Accelerate to -50 rpm at -40 rpm/sec
6-7	Reverse Time, 240 sec at -50 rpm
7-8	Decelerate to 0 rpm at 40 rpm/sec
8-9	Dwell Time, 60 sec at 0 rpm

The PV testing followed the cycle described in Table II. The seal rings were monitored for failure using a thermocouple configured to detect failures such as scoring, galling, and leaks. Weep was defined by the instant that

dyed oil was present at the sealing face. Leak was defined by any amount of oil leaving the sealing region. The PV testing showed that seal rings made from the chromium and boron containing alloys of the present disclosure exhibited the same or better performance (higher PV values) in PV testing as more expensive
5 seal rings made from commercially available, high Ni alloys, including PV values ranging from 600-800 KN/mm - mm/min.

Industrial Applicability

The disclosed chromium and boron containing cast iron alloy for a seal ring, a seal ring for a seal assembly, and a method of making a seal ring
10 may be applicable to the lower powertrain of machines and equipment used in harsh environments, such as mining and quarry products. A seal ring constructed according to principles of the present disclosure generally exhibit improved life, improved scoring pressure velocity, acceptable corrosion resistance, and ease of manufacturing. The seal rings disclosed herein can be offered on new
15 equipment, or can be used to retrofit existing equipment.

In an embodiment, there is described a method for preparing a seal ring according to the present disclosure. Referring to FIG. 4, steps of an embodiment of a method 400 for preparing a seal ring for a seal assembly as disclosed are shown. The seal ring is produced from an alloy following
20 principles of the present disclosure (step 410). The seal ring is machined to at least one predetermined tolerance (step 420). The sealing face of the seal ring is lapped to define an inner relieved area (step 430). The sealing face of the seal ring is lapped to flatten a sealing band (step 440). The sealing band is polished (step 450).

25 The seal ring can be produce in step 410 using any suitable technique, such as by being stamped and formed or cast, for example. In an embodiment, the seal ring is produced by a casting technique, such as by a static mold casting or centrifugal casting. A casting technique includes melting an alloy composition as described herein, e.g., such as an alloy comprising each of
30 B, Cr, and Si in the following amounts B in amounts up to 1.5 wt. %, Cr in amounts ranging from 8.0 to 14.0 wt. %, and Si in amounts up to 3.0 wt. %.

The method according to this embodiment further comprises pouring the melted alloy into a mold at a temperature ranging from 1370 °C to

1482 °C. The melted alloy is then cooled in the mold to form a cast iron seal ring, separating the cast iron seal ring from the mold, and machining the seal ring to at least one predetermined tolerance.

While not shown in FIG. 4, it is understood that the method of preparing a seal ring according to the present disclosure may further comprise a step for heat treating the cast iron seal to change at least one physical or mechanical property of the alloy. For example, the method may comprise heat treating the cast alloy to change the microstructure to comprise a desired carbide phase and one or more desired crystalline phases chosen from martensite and austenite.

In an embodiment, the method comprises heat treating the cast iron composition to achieve a microstructure comprising less than 50 wt. % carbide, such as between 5 to 45 wt. % carbide, or 10 to 40 wt. % carbide, or even 15 to 35 wt. % carbide, or any combination of these ranges, such as 35 to 40 wt. % carbide.

In an embodiment, the method comprises heat treating the cast iron composition to achieve a microstructure having at least 50 wt. % of martensite, austenite and combinations thereof. For example, in various embodiments, the method comprises heating treating the cast iron composition to achieve a microstructure comprising martensite, austenite and combinations thereof in amounts ranging from 50 to 95 wt. %, 55 to 90 wt. %, 60 to 85 wt. %, 70 to 80 wt. %, or any combination of these ranges, such as 80 to 95 wt. %. The method comprises heating treating the cast iron composition to achieve a microstructure to achieve primarily martensite, such as at least 75 wt. % martensite, such as 80 to 95 wt. % martensite, or even substantially all martensite, e.g., at least 99% of this phase is martensite. In an embodiment, phase identification can be determined by Scanning Electron Microscopy (SEM) analysis.

As defined herein, heat treating comprises an annealing step, a tempering step, or both and annealing and tempering step. In an embodiment, the annealing step comprises heating the cast iron seal to a temperature ranging from 700 to 800 °C, such as 750 °C, for a time ranging from 1 to 3 hours, such as 2 hours, followed by cooling to less than 200 °C, such as 150 °C at a rate ranging from 25 to 35 °C per hour, such as 30 °C per hour. In an embodiment, the

tempering step comprises heating at a temperature from 200 to 250 °C, such as 225 °C for a time ranging from 1 to 3 hours, such as 2 hours.

Either prior to or after heat treating, the seal ring can be machined as shown in step 420 of FIG. 4. In step 420, the seal ring can be machined by
5 any suitable technique, such as by using a lathe for lathe-turning and/or grinder for grinding operations, for example. The seal ring can be machined such that the thickness of the seal flange is within a predetermined tolerance, the seal ramp angle is within a predetermined tolerance, and other dimensional tolerances are met, for example. In an embodiment, the resulting seal ring has a hardness
10 ranging from 55 HRC to 70 HRC, such as 68 HRC.

In addition to the hardness properties, the seal ring made according to the present disclosure exhibits a scoring pressure velocity ranging from 300 - 1000 KN/mm - mm/min, such as from 600 to 800 KN/mm - mm/min.

In step 430, the sealing face can be lapped using any suitable
15 technique, such as with a spherical lap, for example, to define the inner relieved area. In step 440, the sealing face can be lapped using any suitable technique, such as with a flat lap, for example, to flatten the sealing band. In embodiments, the sealing band can be polished in step 440 using any suitable technique.

It will be apparent to those skilled in the art that various
20 modifications and variations can be made to the disclosed alloy and method of forming the alloy into a finished part without departing from the scope of the disclosure. Alternative implementations will be apparent to those skilled in the art from consideration of the specification and practice disclosed herein. It is intended that the specification and examples be considered as exemplary only,
25 with a true scope of the disclosure being indicated by the following claims and their equivalents.

Claims

1. A seal ring (100), comprising a body having a cast iron composition comprising B, Cr, and Si in the following amounts:

5 B: up to 1.5 wt. %;
Cr: 8 to 14 wt. %; and
Si: up to 3 wt. %.

2. The seal ring (100) of claim 1, wherein B is present in an amount ranging from 0.5 to 1.0 wt. %, Cr is present in an amount ranging from
10 10 to 14 wt. %, Si is present in an amount ranging from 1.5 to 2.4 wt. %.

3. The seal ring (100) of claim 1, wherein the cast iron composition further includes:

15 C: 2.8 to 3.6 wt. %;
Mn: 0.40 to 1.0 wt. %;
Ni: 3.0 to 5.0 wt. %;
V: up to 1.0 wt. %;
Mo: up to 0.80 wt. %;
P: up to 0.08 wt. %;
20 S: up to 0.2 wt. %; and

the balance comprising Fe and incidental impurities.

4. The seal ring (100) of claim 1, wherein the cast iron composition has a microstructure comprising less than 50 wt. % carbide and
25 more than 50 wt. % of martensite, austenite and combinations thereof.

5. The seal ring (100) of claim 1, wherein:
the body is generally cylindrical (140) and extends along a longitudinal axis between a load end (145) and a seal end (150); and
30 the seal ring (100) further includes the seal flange (105) disposed at the seal end (150) of the body, the seal flange (105) circumscribing the body (140) and projecting radially from the body to a distal perimeter of the seal flange (105), the seal flange (105) including a sealing face (110) that is annular and disposed adjacent the distal perimeter (120).

6. A method of making a cast iron seal ring (100),
comprising:

melting an alloy composition comprising each of B, Cr, and Si in
the following amounts:

5 B: up to 1.5 wt. %;
 Cr: 8 to 14 wt. %; and
 Si: up to 3 wt. %;

 pouring the melted alloy into a mold;
 cooling the melted alloy to form a body;
10 separating the body from the mold; and
 machining the body to at least one predetermined tolerance.

7. The method of claim 6, further comprising heat treating
the body to change at least one physical or mechanical property of the alloy.
15

8. The method of claim 7, wherein heat treating comprises
an annealing step, a tempering step, or both an annealing and tempering step.

9. The method of claim 8, wherein said annealing step
20 comprises heating the body to a temperature ranging from 700 to 800 °C for a
time ranging from 1 to 3 hours, followed by cooling to less than 200 °C at a rate
ranging from 25 to 35 °C per hour; and
 said tempering step comprises heating at a temperature from 200
to 250 °C for a time ranging from 1 to 3 hours.

25 10. The method of claim 6, wherein said pouring occurs at a
temperature ranging from 1370 °C to 1482 °C.

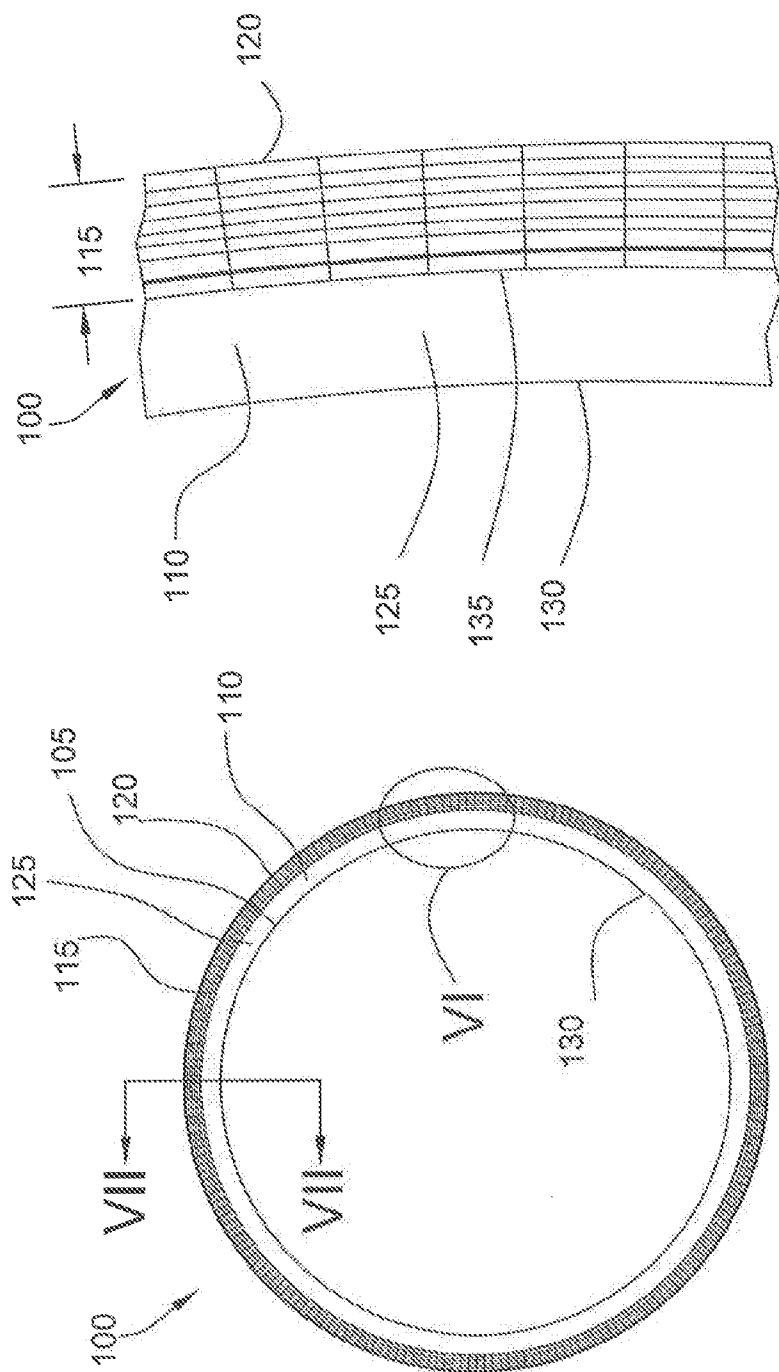
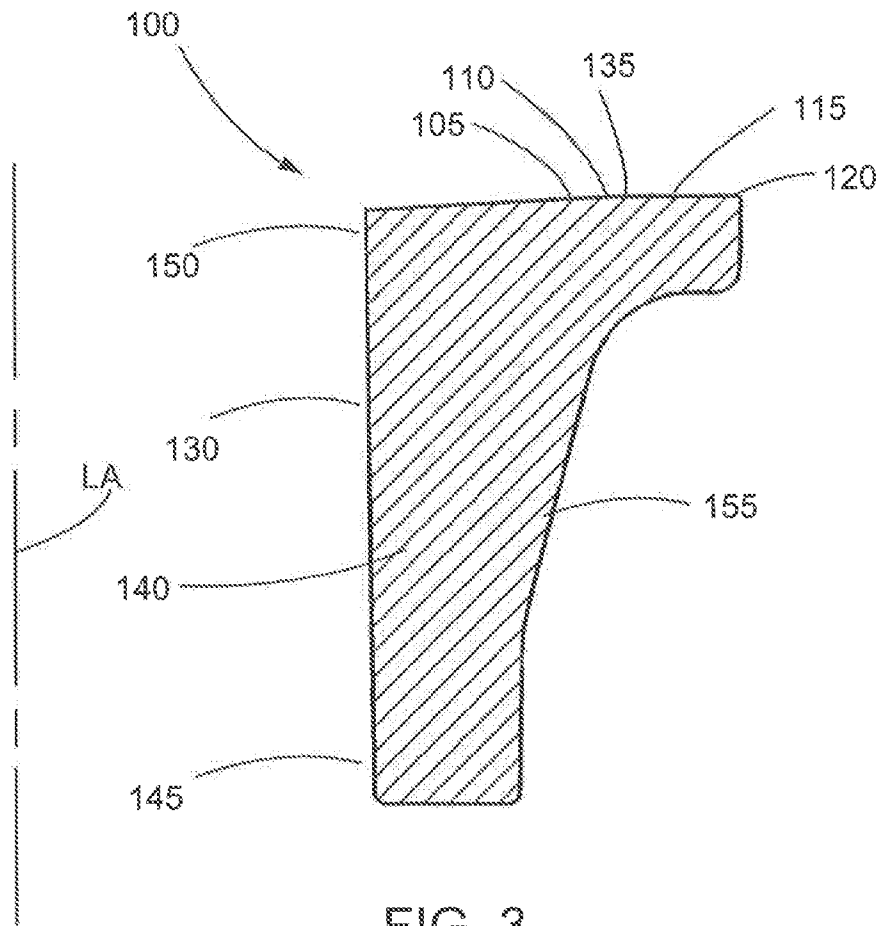


FIG. 1

FIG. 2

2/3



3/3

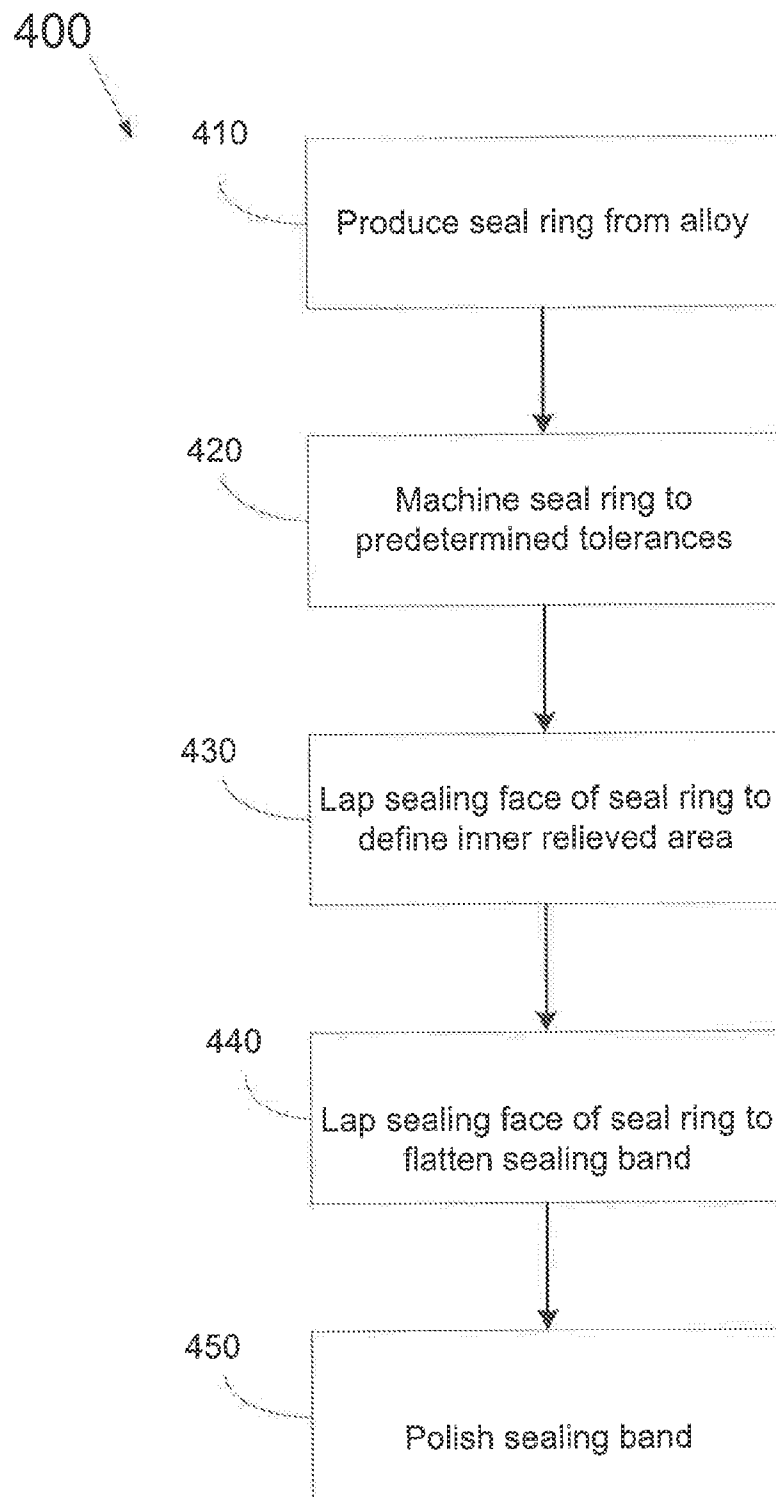


FIG.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/064089

A. CLASSIFICATION OF SUBJECT MATTER

INV. C22C37/06 C22C37/08 C22C37/10 F16J15/34 B22D13/02
C21D5/00 C21D5/02

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C B22D F16J C21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X A	----- US 2014/300060 A1 (NISHIOKA MASATO [JP]) 9 October 2014 (2014-10-09) claims 1-2 paragraph [0009] - paragraph [0025] figures 1-2	1-8,10 9
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

16 February 2017

Date of mailing of the international search report

23/02/2017

Name and mailing address of the ISA/

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Vlassi, Eleni

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/064089

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	claims 1-11 table 1 -----	1-3,5-10
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Information on patent family members

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