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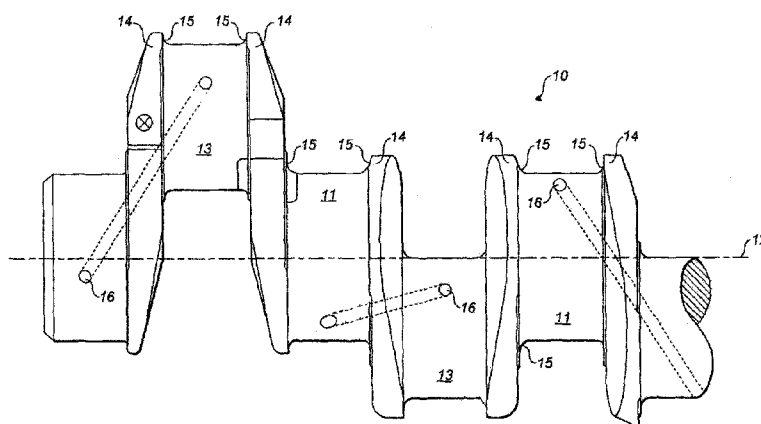


FIG. 1

(57) Abstract: The invention relates to improvements in the induction hardening of crankshafts made from spheroidal graphite (SG) cast iron containing an orifice. At least one selected portion of the crankshaft is heated by induction heating from ambient temperature, at which the structure of the spheroidal graphite cast iron is pearlite, to a temperature at which the structure of the spheroidal graphite cast iron transforms to austenite. The crankshaft is subsequently cooled in a gaseous medium, such as air, to a temperature at which the structure of the spheroidal graphite cast iron transforms at least in part to martensite.

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METHOD FOR INDUCTION HARDENING OF CRANKSHAFTS MADE FROM SPHEROIDAL GRAPHITE
CAST IRON AND INDUCTION HARDENED CRANKSHAFT

TECHNICAL FIELD

5 The invention relates to improvements in the induction hardening of crankshafts made from spheroidal graphite (SG) cast iron.

BACKGROUND

10 It is a known practice to improve the wear and fatigue characteristics of components, such as crankshafts, by induction hardening. Induction hardening is a form of heat treatment which uses an electromagnetic induction coil to produce localised heating. The heated component is
15 subsequently cooled by quenching with a liquid to induce a metallurgical transformation to produce a hardened surface. Induction heating is a particularly convenient process to achieve this as it is a non-contact heating process which can target a specific area, or areas, of the component. This
20 is particularly desirable for crankshafts which have a number of bearing surfaces provided by the main journals ("mains"), and the crankpins ("pins"), the axes of which are offset from that of the main journals, with oil ducts connecting the mains and the pins.

25

 When induction hardening components such as crankshafts and the like, which include oil ducts or other orifices, surface cracking may occur in the component particularly where the oil duct is not at a right angle to the component
30 surface. This may be attributable to the masses of metal between the oil duct and the crankshaft surface being largely unequal, though various other causes have been proposed .

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Cast iron has a number of advantages for use in automotive parts, such as crankshafts, in that it is less expensive than steel, is easy to cast and machine, has good wear and deformation resistance and has a reasonable tensile strength. However many cast irons tend to be brittle. SG cast iron, on the other hand, is more flexible and elastic than most varieties of cast iron, and has a similar stress strain curve to that of steel.

The prior art induction process works well for forged steel components, but it has been found that surface cracking can occur within the oil duct of components made from other materials, such as crankshafts made from spheroidal graphite (sg) cast iron.

SUMMARY

According to the present disclosure there is provided a method of induction hardening a crankshaft made from spheroidal graphite cast iron, comprising the steps of selecting at least one portion of the crankshaft to be hardened; heating only the at least one selected portion by induction heating from ambient temperature, at which the structure of the spheroidal graphite cast iron is pearlite, to a temperature at which the structure of the spheroidal graphite cast iron transforms to austenite, and subsequently cooling the at least one selected portion in a gaseous medium to a temperature at which the structure of the spheroidal graphite cast iron transforms at least in part to martensite .

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The present disclosure further comprises an induction hardened crankshaft in which at least a portion of the surface has been heated by induction heating from ambient temperature, at which the structure of the spheroidal graphite cast iron is pearlite, to a temperature at which the structure of the spheroidal graphite cast iron transforms to austenite, and subsequently cooled in a gaseous medium to a temperature at which the structure of the spheroidal graphite cast iron transforms at least in part to martensite.

BRIEF DESCRIPTION OF THE DRAWINGS

A non-limiting embodiment of an induction hardened crankshaft produced by the method of the present disclosure is now described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a side elevation of a part of a crankshaft for an internal combustion engine;

Figure 2 is a schematic diagram showing localised sites of induction hardening; and

Figure 3 is a schematic diagram showing additional localised sites of induction hardening.

DETAILED DESCRIPTION

Figure 1 illustrates one example of a component which may be induction hardened by the method of the present disclosure. The component is in the form of a crankshaft for an internal combustion engine and includes oil ducts. Crankshafts generally comprise main journals aligned on the crankshaft axis which provide highly polished radially facing circumferential bearing surfaces on which the main bearings may be mounted. Located between the main

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journals 11, and offset from the crankshaft axis 12, may be crankpins 13, which may be highly polished surfaces to which the connecting rods can attach.

5 The main journals 11 and crankpins 13 may be connected by webs 14. The webs may have opposed surfaces, each defining an annular face arranged immediately adjacent the respective journal 11 or crankpin 13 and which may serve during machining as a reference plane. Where the main
10 journals 11 and crankpins 13 attach to the annular faces there may be a radiussed fillet 15. Each adjacent pair of main journals and crankpins 11,13 may be interconnected by oil ducts which may extend away from an orifice 16 in the surface of said main journals and crankpins 11,13 to
15 distribute lubricant therebetween.

 In an alternative arrangement, the fillets 15 may be undercut, as shown in Figure 2. This may be to accommodate fillet rolling, which is a mechanical process used to
20 compress the material in the vicinity of the fillet radius to strengthen the crankshaft 10. Furthermore the orifices 16 may have a chamfer 17 at their mouths in the journal surfaces .

25 The crankshaft 10 is made from SG cast iron, which is also known as ductile iron or nodular iron and is available in different grades, which are characterised by their tensile strength and elongation. For example, the crankshaft 10 may be made from SG cast iron material grade
30 850/3 which would have a minimum tensile strength of 850MPa with a minimum elongation of 3%.

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The induction hardening process may be carried out by an induction machine. The crankshaft 10 may be held in the machine and arranged to rotate about the axis of the main journals 11. The machine may include a number of identical
5 (or at least similar) tools arranged in a row, each tool being designated for a particular journal 11,13. The tools assigned to the main journals 11 may remain substantially stationary while tools assigned to the crank pins 13 may move therewith as they rotate around the axis of the main
10 journals 11. Each tool generally comprises a "heating portion" and a "cooling portion".

The heating portion of the tool may comprise a copper inductor having a semicircular recess at its lower face
15 which is sized to locate around its respective journal 11,13. The inductors provide an alternating magnetic field which induces an electrical current within the metal, thereby creating heat. The inductors may be generally fork-shaped and may be designed for the geometry of the
20 component being hardened, the desired hardening requirements and the material of the component undergoing treatment. The copper inductors, usually with steel lamination flux intensifiers, receive electrical power for a pre-determined period in order to generate sufficient heat to raise the
25 crankshaft temperature to the required level. For example, it may be necessary to raise the temperature of the required portion of the component from ambient temperature (about 20°C) to approximately 850°C to achieve the desired initial metallurgical transformation, i.e. pearlite to austenite.
30 The electrical power and pre-determined period may be inversely proportional such that greater electrical power results in a reduced heating period. For example, approximately 40-50 kW of electrical power may be directed

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to each copper inductor over a pre-determined period of 16 seconds for the crank pins 13 and 20 seconds for the main journals 11.

5 Optionally, the process may include a brief pause between the heating step and the cooling step to allow any localised temperature gradients to equalise. This step may last for as little as several seconds and during which time no power or coolant may be directed through the tool.

10

 The cooling portion of the tool may include various pipes carried on the tool and nozzles provided on the end of the pipes may be arranged near the semi-circular recess for delivering coolant to the heated surface. In the
15 aforementioned prior art process the liquid coolant typically comprises a specially formulated polymer quenchant and may be delivered at, for example, approximately 3.5 bar (350 KPa) pressure and at a quench temperature of 25°C. Quenching time may vary according to various factors, such as quenchant
20 pressure, quenchant temperature, the initial material temperature and the desired quenched temperature. Typically the quenchant time may be around 10 seconds to bring the component temperature to around 100 °C.

25 Once quenched, the crankshaft 10 may be moved to a cold shower to remove any residual heat and reduce its temperature for mechanical handling, although this step is optional .

30 According to the present disclosure, induction hardening is achieved at one or more selected portions 20 of the crankshaft 10 using a modified version of this prior art process. The modified process comprises heating the

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crankshaft from ambient temperature and cooling it using a gaseous medium to a temperature at which the structure of the spheroidal graphite cast iron transforms to martensite.

5 In the first example shown in Figure 2, the selected portion (s) 20 may include portions of the surfaces of the main journals 11 and crankpins 13 of the crankshaft 10. In the second example shown in Figure 3, the selected portions 20 may include portions of the surfaces of the main journals 10 11, the crankpins 13 and also the radiuses 15 and possibly a portion of the annular faces 21 proximal to the radiussed fillets 15. Hardening of the aforementioned surfaces helps to improve, in particular, wear resistance. Hardening of the radiussed fillets 15 helps, in particular, to improve 15 fatigue resistance. In both examples, the induction hardening process may include the steps of locating the copper inductors over the journals and crankpins 11,13, rotating the crankshaft 10 and then directing electrical power of a predefined magnitude through the copper inductors 20 for a predetermined time. The shape and location of the copper inductors may vary slightly depending on the size of the selected areas to be heated and, as such, the copper inductors used to heat the different crankshafts 10 shown in Figures 2 and 3 are of different shapes. The electrical 25 power and the pre-determined time may be selected according to the desired temperature of the selected surface of the component 10, which may be in excess of 850°C. For example, the electrical power through each copper inductor may be around 40-50kw and the pre-determined time may be 30 approximately 20 seconds.

The cooling step of this method requires the crankshaft 10, or more particularly the selected portions 20 of the

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surfaces, to be subjected to a coolant in the gaseous phase. For instance, the coolant may be at atmospheric pressure and applied to the selected surfaces for a predetermined time. Alternatively, the coolant may be pressurised so as to
5 reduce the predetermined time for which the selected surfaces are exposed to the coolant. The coolant may comprise air or alternative gaseous compositions.

In terms of metallurgy, as the SG iron is heated from
10 ambient (room) temperature its structure transforms from pearlite to austenite. When the SG iron is cooled or quenched to a certain temperature the austenite transforms to martensite, which is hard. It is the metallurgical transformation, either in full or part, that produces the
15 hardened portions 20. Where a partial transformation occurs austenite is present with the martensite. As austenite is relatively soft, whilst martensite is significantly harder, it may be desirable to have a greater proportion of martensite in the selected areas of the component.

20

The temperature to which the crankshaft is cooled may be 180°C, or 150°C or 100°C. The cooling rate may also affect the metallurgical transformation and may be at least 5°C per second, or at least 3°C per second. Faster cooling
25 rates may be chosen for commercial reasons to speed up the production process.

The size of the crankshafts 10 may vary according to the size of the engine in which they are to be installed.
30 In one of the examples shown in the figures, the diameter of the main journals is 76mm and the diameter of the crankpins is 68mm. In the other example shown in the figures, the diameter of the main journals is 84mm and the diameter of

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the crankpins is 68mm. The above described process results in a hardened portion 20 of approximately 2mm deep, although the depth can be adjusted by varying the parameters associated with the tools and the process.

5

INDUSTRIAL APPLICATION

The process described herein has been shown to reduce the severity and speed of quenching and to produce less stress in the oil ducts 16. This provides a corresponding reduction in surface cracking. This process produces at least a layer of hardened material through which any cracks occurring in the unhardened material below this layer cannot propagate. The SG iron "hardenability" is very high and the gaseous cooling allows the metallurgical transformation to occur .

The method has industrial applicability in the production of crankshafts 10 and other components made from SG iron which require induction hardening to reduce distortion, to limit wear and mechanical damage and to enhance strength.

In many prior art processes, the whole component is heated in a preliminary heat treatment prior to induction hardening, to effect desired metallurgical changes prior to the induction heating step. This means that there is a large mass of material at a high temperature (both before and after the induction hardening step) . In the process of the present disclosure the induction hardening step is commenced when the component is at ambient temperature, and on selected portions only, so the overall temperature of the component is lower. This has an impact on the required

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cooling parameters, in particular the cooling rate.
Furthermore the operator does not have to handle very hot components to place them in the induction machine.

- 5 This process enables the use of a gaseous medium for quenching, which provides a less severe quenching effect than liquid. However the cooling step must be performed in a manner which enables sufficient metallurgical transformation of austenite to martensite to occur to avoid the
- 10 aforementioned cracking problems. If the cooling conditions are not right, the transformation may produce bainite, which does not have the desired properties of martensite, or pearlite may reform.

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CLAIMS :

1. A method of induction hardening a crankshaft made from spheroidal graphite cast iron comprising the steps of
5 selecting at least one portion of the crankshaft to be hardened; heating only the at least one selected portion by induction heating from ambient temperature, at which the structure of the spheroidal graphite cast iron is pearlite, to a temperature at which the structure of the spheroidal
10 graphite cast iron transforms to austenite, and subsequently cooling the at least one selected portion in a gaseous medium, to a temperature at which the structure of the spheroidal graphite cast iron transforms at least in part to martensite .
- 15 2. A method as claimed in claim 1, wherein the gaseous medium in which the selected portion is cooled is air.
3. A method as claimed in claim 1 or claim 2, wherein the
20 gaseous medium is above atmospheric pressure.
4. A method as claimed in any one of the preceding claims in which the selected portion is heated to at least 850°C.
- 25 5. A method as claimed in any one of the preceding claims, wherein the selected portion is heated for about 20 seconds.
6. A method as claimed in any one of the preceding claims, wherein the main journal or journals define a crankshaft
30 axis about which the crankshaft is rotated during the heating step.

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7. A method as claimed in any one of the preceding claims, in which the selected portion is cooled to a temperature of 180°C or less.

5 8. A method as claimed in claim 7, wherein the selected portion is cooled to a temperature of 100°C or less.

9. A method as claimed in any one of the preceding claims, in which the selected portion is cooled at a rate of at
10 least 3°C per second.

10. A method as claimed in any one of the preceding claims, in which the selected portion is cooled at a rate at least 5°C per second.

15 11. A method as claimed in any one of the preceding claims, wherein the selected portion is cooled in the gaseous medium for a duration of between 5 and 120 seconds.

20 12. A method as claimed in claim 11, wherein the selected portion is cooled in the gaseous medium for a duration of 20 seconds .

25 13. A method as claimed in any one of the preceding claims, wherein the crankshaft further includes at least one web disposed between an adjacent main journal and crankpin, wherein the step of selecting a portion to be hardened includes selecting at least one main journal, at least one crankpin and parts of the webs immediately adjacent the
30 selected main journals and crankpins .

14. An induction hardened crankshaft in which at least a portion of the surface has been heated by induction heating

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from ambient temperature, at which the structure of the spheroidal graphite cast iron is pearlite, to a temperature at which the structure of the spheroidal graphite cast iron transforms to austenite, and subsequently cooled in a
5 gaseous medium to a temperature at which the structure of the spheroidal graphite cast iron at least in part transforms to martensite.

15. An induction hardened crankshaft as claimed in claim 14
10 comprising at least one main journal and at least one crankpin with an oil duct formed between adjacent main journals and crankpins .

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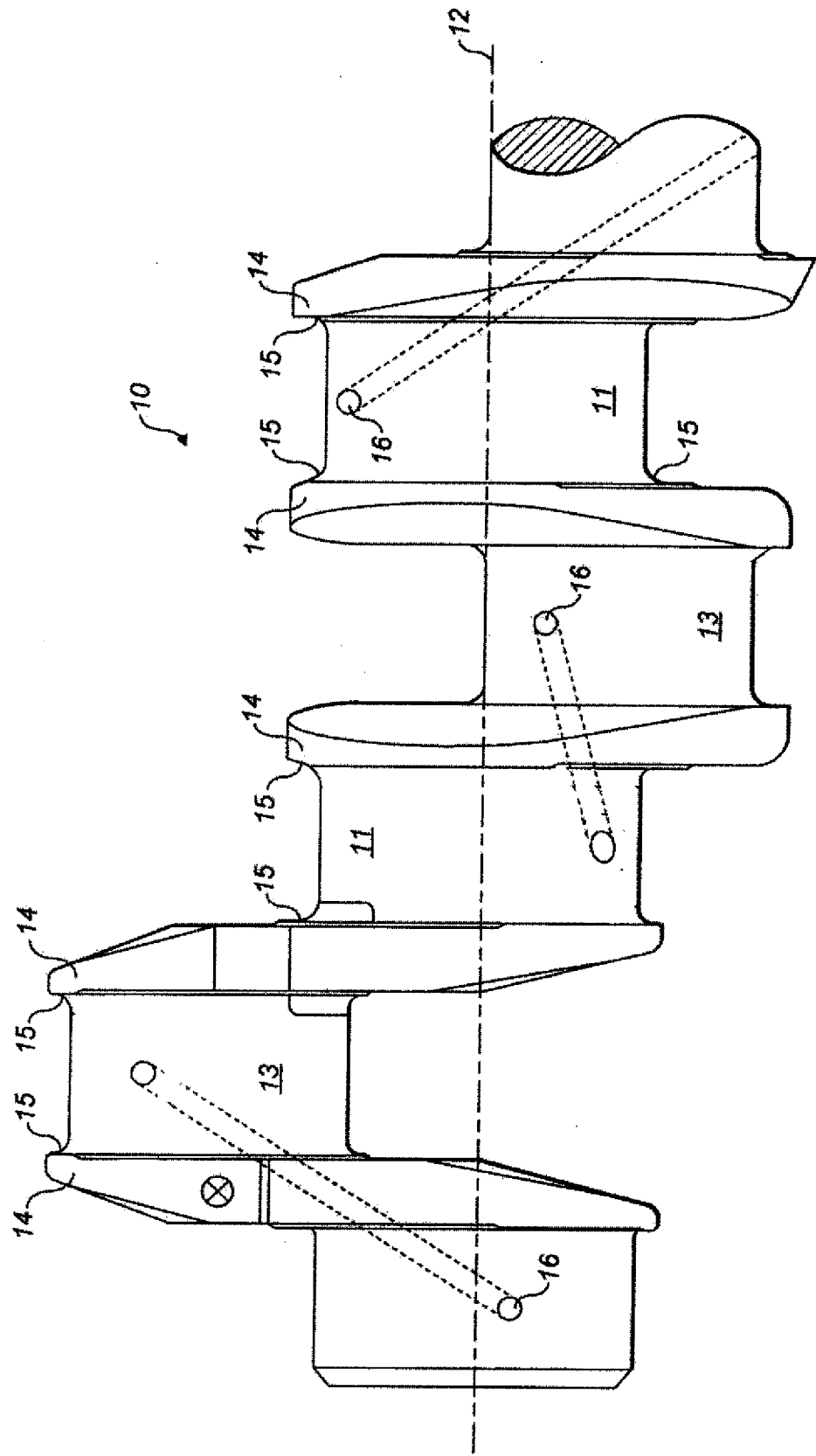
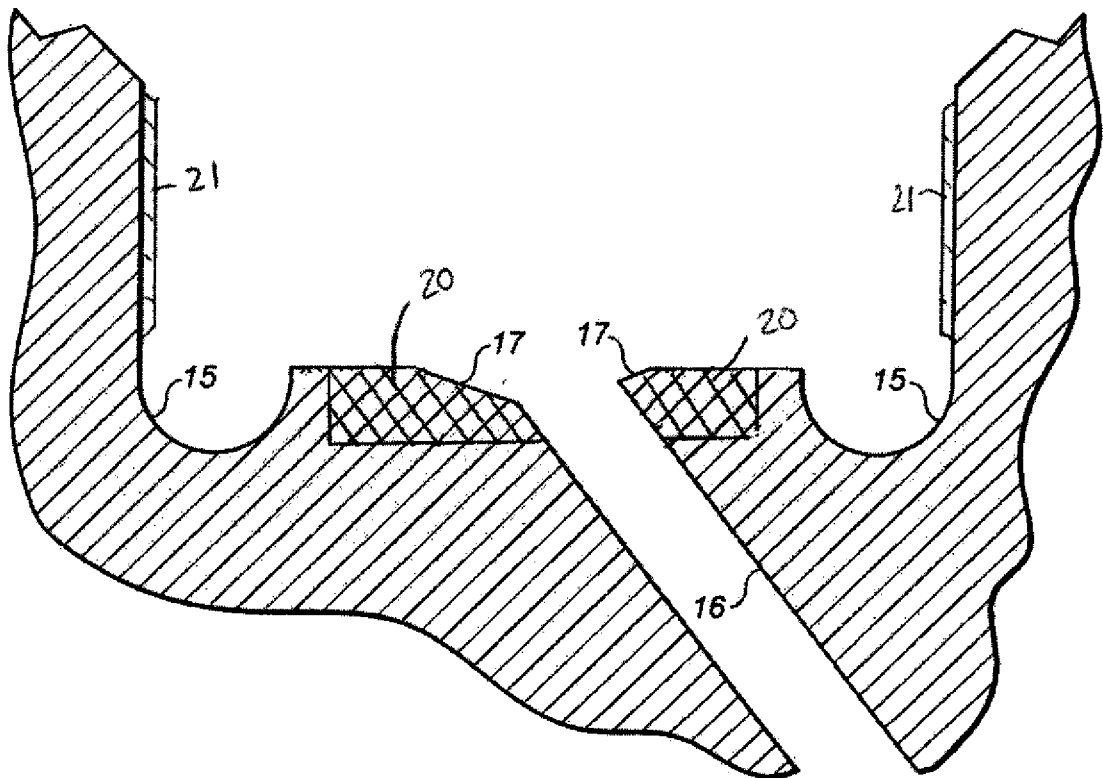
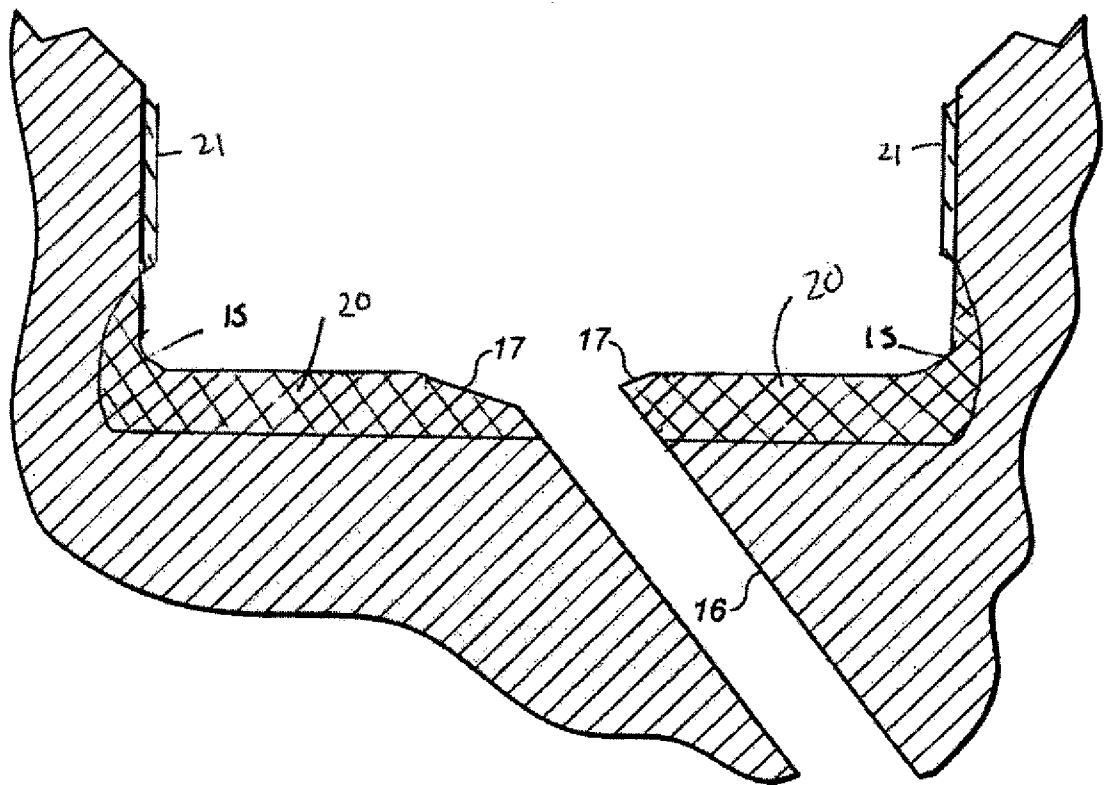


FIG. 1

**FIG. 2**

**FIG. 3**

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER INV. C21D1/10 C21D9/30 F16C3/06 ADD.		
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C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	wo 2010/100106 AI (KESSLER KG MASCHF [DE] ; SCHMIDT JOCHEN [DE] ; ZAHN ANDREAS [DE] ; EBERLE) 10 September 2010 (2010-09-10) page 11, paragraph 2 - paragraph 3 page 10, paragraph 3; figure 3 -----	1-15
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Ri schard, Marc

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