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(54) Title: A ROCKER ARM AND A ROCKER ARM ASSEMBLY

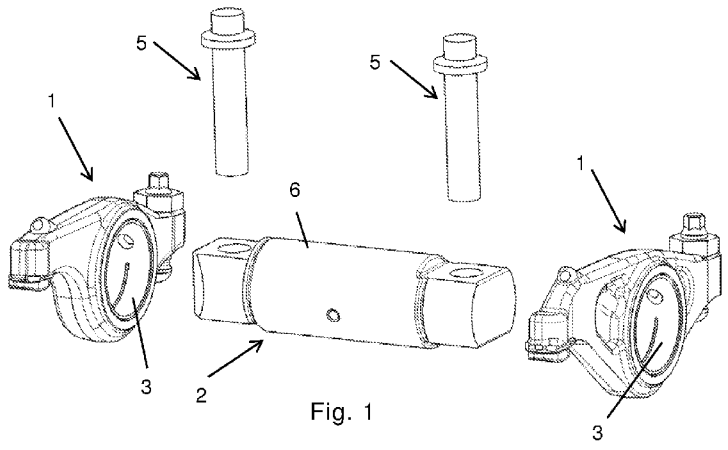

Fig. 1

(57) Abstract: A rocker arm (1) and a rocker arm assembly, wherein the rocker arm has a through-hole for rotatably receiving a support shaft (2). The rocker arm is manufactured from steel and the through- hole is delimited by an outer surface (3) of a bearing surface zone comprising an elevated amount of nitrogen and having an increased hardness with respect to a steel matrix below the bearing surface zone. The support shaft is preferably manufactured from ductile cast iron.

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A rocker arm and a rocker arm assembly

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a rocker arm according to the preamble of claim 1 and a rocker arm assembly according to the preamble of claim 8. Such a rocker arm and rocker arm assembly are used in motor vehicles, in particular in vehicles comprising an internal combustion engine.

BACKGROUND AND PRIOR ART

A conventional internal combustion engine of piston type, a so-called piston engine, is provided with one or more cylinders. In each cylinder a piston is configured to reciprocate under the action of the pressure which occurs upon ignition of a fuel-air mixture introduced into the cylinder. In a piston engine of four-stroke type, each cylinder is provided with at least one inlet valve via which the fuel-air mixture is drawn into the cylinder, and at least one exhaust valve via which combustion gases are removed from the cylinder. For this purpose, the inlet valve and the outlet valve are movable between a closed an open position. The valves may also be actuated for other reasons than for the inlet and outlet related to combustion. An example of this function is decompression braking, in which the valves are engaged without combustion to obtain a retarding effect of the crankshaft.

The inlet valve and the exhaust valve are each spring-loaded to a closed position and are each movable from closed to open position by the action of a control cam on a rotating camshaft. The control cam is normally configured to act upon the valve via a so-called rocker arm, which is provided with a through-hole for rotatably receiving a support shaft or a bearing bracket. The rocker arm is commonly manufactured from steel or cast iron and the support shaft is commonly manufactured from steel. However, if the valves are to be used also for decompression braking, the demands on the mechanical strength of the rocker arm increases and it is usually not possible to use a cast iron rocker arm.

A plain bearing is usually provided between the support shaft and the through-hole to minimise the risk of seizure and wear during relative motion of the parts arising during relative rotational motion. Such plain bearings used between the rocker arm and the support shaft include sleeve bearings typically comprising leaded bronze, providing a lubricating film of lead at the bearing interface. However, for environmental reasons and in order to meet increasingly strict legal requirements regarding leaded products, it is desirable to develop an alternative solution to the use of such bearings. Furthermore, bronze sleeve bearings, including lead-free such bearings, exhibit an impaired performance in acid environments. Modern engine oils have less ability to buffer acids, resulting from oxidation of the engine oil and contamination via condensation and combustion by-products. Thus, the performance of the bearings is negatively affected, especially for lead-containing bearings and bearings based on bronze or other yellow metals.

A further problem with bronze sleeve bearings, in particular for heavy motor vehicles such as trucks and buses, is that high wear arises when the vehicle is equipped with a so-called stop-start system. Such a system is increasingly common and automatically shuts down the combustion engine when the vehicle is stopped in order to save fuel and to reduce emissions.

SUMMARY OF THE INVENTION

It is a primary objective of the present invention to provide a rocker arm and a rocker arm assembly which are in at least some aspect improved with respect to known such components. In particular, it is an objective to provide a rocker arm and a rocker arm assembly by means of which the above mentioned problems are overcome. Another objective is to provide a rocker arm and a rocker arm assembly with a mechanical strength such that the rocker arm and the rocker arm assembly are suitable for use in connection with decompression brakes.

At least the primary objective is, according to a first aspect of the present invention, achieved by a rocker arm having a through-hole for rotatably receiving a support shaft, wherein the rocker arm is manufactured from steel and wherein the through-hole is delimited by an outer surface of a bearing surface zone, which is characterised in that the bearing surface zone comprises an elevated amount of nitrogen and has an increased hardness with respect to a steel matrix below the bearing surface zone.

The hardened surface zone at least around the through-hole together with the steel core of the rocker arm provides a combination of core toughness and surface hardness. The rocker arm has a high mechanical strength and is thereby suitable for being used in connection with compression braking. The hardened surface zone provides increased wear resistance and resistance to seizure in the bearing interface between the rocker arm bearing surface zone and a contact surface of a support shaft mounted in the through-hole, and it also reduces the friction arising upon relative movement of the parts. Such a surface zone with increased hardness can be in the form of a conversion coating formed on the steel matrix of the rocker arm. The hardened surface zone may, apart from nitrogen, also comprise an elevated amount of carbon.

The steel should be a steel suitable for being subjected to a nitriding or a nitrocarburising process, such as a steel for quenching and tempering with a typical hardness in the range between 150 to 350 HV. The steel is preferably such that a compound layer is provided when the steel is subjected to a nitriding process. The hardness of the bearing surface zone should preferably be at least 500 HV, and can be significantly higher, such as 1000 HV and above.

According to one embodiment of the invention, the bearing surface zone has been formed in a nitriding process or in a nitrocarburising process. There are a plurality of different suitable nitriding and nitrocarburising processes which result in an increased hardness of the surface zone. Nitriding and nitrocarburising have the advantage over other surface hardening

methods that the required process temperature is low, typically 400–650 °C, of which nitriding temperatures are typically 480–550 °C, and nitrocarburising temperatures are typically 550–650 °C. The rocker arm can thereby be nitrided in a fully hardened and tempered condition without the core properties of the steel being adversely affected. Nitriding generally diffuses nitrogen into the surface zone, thus increasing the concentration of nitrogen, while nitrocarburising also diffuses carbon into the surface zone. It is possible to mask part of the rocker arm during the nitriding or nitrocarburising process if it is desired that only the surface zone delimiting the through-hole should be hardened. However, it is also possible to leave the rocker arm unmasked and obtain a surface layer of increased hardness on the entire rocker arm.

According to one embodiment of the invention, the bearing surface zone is a nitrided surface zone. Such a nitrided surface zone can be achieved by e.g. gas nitriding and exhibits the desired properties regarding resistance to seizure, hardness and wear resistance.

According to one embodiment of the invention, the bearing surface zone comprises an outer compound zone having a thickness within a range of 5–50 µm. Such a compound zone, sometimes referred to as a “white layer”, is a phase transformed layer achieved during a nitriding or a nitrocarburising process and provides excellent resistance to seizure, wear resistance and corrosion resistance to the bearing surface zone. With a thickness of at least 5 µm, sufficient wear resistance and durability is achieved. Making the compound zone too thick

requires very long processing times, and furthermore reduces the quality of the compound layer. Preferably, the outer compound zone has a thickness within a range of 10–20 µm.

According to one embodiment of the invention, a diffusion zone with an inward gradually decreasing hardness is formed between the outer compound zone and the steel matrix, said diffusion zone having a thickness within a range of 50–800 µm, preferably 100–400 µm. Such a diffusion layer provides a gradual transition from the high hardness of the surface to the relatively low hardness of the steel matrix of the core and thereby increases the structural strength of the rocker arm. Preferably, the hardness of the diffusion zone at an interface toward the outer compound zone is at least 450 HV.

According to another aspect of the present invention, at least the above mentioned primary objective is achieved by means of a rocker arm assembly comprising a support shaft and at least one rocker arm as proposed, wherein the rocker arm is configured to be rotatably mounted around the support shaft. Advantages and advantageous embodiments of such an assembly appear from the above description of the proposed rocker arm. The support shaft can be in the form of a long support shaft supporting several rocker arms, or in the form of one or several bearing brackets having an integrated shaft member, depending on the design of the engine in which the rocker arm assembly is operating. Normally, the support shaft is fixed in the rocker arm assembly, and the rocker arm rotationally pivots around the support shaft.

According to one embodiment of this aspect of the invention, the outer surface of the bearing surface zone of the at least one rocker arm is in rotational contact with a peripheral surface of the support shaft.

According to one embodiment of this aspect of the invention, the support shaft is manufactured from cast iron. Preferably, the cast iron is in the form of ductile cast iron. Ductile cast iron, also referred to as e.g. spherulitic graphite cast iron and nodular graphite cast iron, contains graphite which provides to some degree a lubricating film at the bearing interface between the rocker arm and the support shaft. The steel with the bearing surface zone provides resistance to seizure in the bearing interface. The combination of the two materials provides a bearing interface without having to use an intermediate plain bearing component, such as a sleeve. This combination of materials thus provides excellent strength and hardness of the rocker arm in combination with the lubricating properties of the support shaft. The ductile cast iron preferably has a minimum tensile strength of 350 MPa and an elongation A5 of minimum 3%. The elongation A5 is defined as the elongation up to the point of fracture of a bar, measured over an initial gauge length of 5 times the bar diameter.

Further advantages and advantageous features of the invention will appear from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of example with reference to the appended drawings, in which:

Fig. 1 shows an exploded view of a rocker arm assembly according to an embodiment of the invention,

Fig. 2 shows a perspective view of the rocker arm assembly in fig. 1, and

Fig. 3 schematically shows a sectional view of a surface zone of a rocker arm according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

An exploded view of a rocker arm assembly according to an embodiment of the invention is schematically shown in fig. 1. The rocker arm assembly comprises two rocker arms 1 and a support shaft 2, which extends along a central axis. Each of the rocker arms 1 comprises a through-hole for rotatably receiving the support shaft 2, such as shown in fig. 2. The rocker arms 1 can thereby rotate around the support shaft 2. Fastening members 5 for fastening the support shaft 2 are provided outside of the rocker arms 1.

The through-hole of each rocker arm is delimited by an outer surface 3 of a bearing surface zone 4, schematically shown in fig. 3. The outer surface 3 is in direct contact with a peripheral surface 6 of the support shaft 2, so that a rotational plain bearing is formed by the outer surface 3 of the bearing surface zone 4 of

the rocker arm 1 and the peripheral surface 6 of the support shaft 2.

The rocker arms 1 are manufactured from steel and are, after hardening and tempering, preferably surface hardened by a nitriding or nitrocarburising process. The steel grade should therefore be suitable for being subjected to such a process, such as a steel for quenching and tempering with a typical hardness in the range between 150 to 350 HV. Suitable steel grades for this purpose fulfill the requirements listed in Swedish standard SS-EN 10083. The support shaft 2 is preferably manufactured from ductile cast iron, i.e. cast iron containing graphite which can act as a lubricant between the peripheral surface 6 and the outer surface 3 of the bearing surface zone 4.

The bearing surface zone 4 of the rocker arm 1, in comparison with a steel matrix 9, comprises an elevated amount of nitrogen, and in some cases also of carbon, as a result of the nitriding or nitrocarburising process. The bearing surface zone 4, as shown in fig. 3, comprises an outer compound zone 7 having a hardness of at least 500 HV, as compared to the core hardness of the steel matrix 9 of the rocker arm 1 of between 150 and 350 HV. The hardness of the compound zone 7 depends on the steel grade used, wherein high-alloy steel grades generally give a compound zone of higher hardness, such as 1000 HV or above. The compound zone typically consists of non-metallic phases formed by iron and nitrogen, such as γ-phase iron nitride (Fe_4N), containing up to 6 wt. % N, and ε-phase ($Fe_{2-3}N$) containing up to 11 wt. % N. In the case when the bearing surface zone 4 has been formed in a nitrocarburising process, the compound zone 7

also comprises iron-carbonitrides. Between the steel matrix 9 and the compound zone 7, a diffusion zone 8 is formed. The diffusion zone 8 has a hardness which gradually decreases from the compound zone 7 and toward the steel matrix 9. The hardness of the diffusion zone 8 at the interface toward the outer compound zone 7 should at least be 450 HV. The diffusion zone contains nitrogen in solid solution as well as stable metal nitrides formed by alloying elements of the steel.

The thickness of the compound zone 7 is typically in the range 5–50 µm, preferably 10–20 µm. The thickness of the compound zone 7 increases with processing time and the ideal thickness is therefore dependent on desired lead times in the production as well as on desired material properties of the rocker arm 1. The diffusion zone 8 typically has a thickness within a range of 50–800 µm, preferably 100–400 µm.

The nitriding or nitrocarburising process used to form the bearing surface zone 4 can be any suitable process used in the field, such as salt bath nitrocarburising, gas nitriding, gas nitrocarburising, low pressure nitriding, low pressure nitrocarburising, plasma nitriding, or plasma nitrocarburising.

The rocker arm assembly may of course comprise a different number of rocker arms than described above, and the support shaft may be accordingly configured. The support shaft can e.g. be in the form of one or more bearing brackets with an integrated shaft member, or a long shaft configured to hold several rocker arms depending on the design of the engine in which the rocker arm assembly is mounted.

The invention is of course not in any way restricted to the embodiments described above. On the contrary, many possibilities to modifications thereof will be apparent to a person with ordinary skill in the art without departing from the basic idea of the invention such as defined in the appended claims.

CLAIMS

1. A rocker arm (1) having a through-hole for rotatably receiving a support shaft (2), wherein the rocker arm (1) is manufactured from steel and wherein the through-hole is delimited by an outer surface (3) of a bearing surface zone (4), wherein the bearing surface zone (4) comprises an elevated amount of nitrogen and has an increased hardness with respect to a steel matrix (9) below the bearing surface zone (4),
characterised in
that the bearing surface zone (4) has been formed in a nitrocarburising process, and in that the bearing surface zone (4) comprises an outer compound zone (7) comprising iron nitrides and iron carbonitrides and having a thickness within a range of 5–50 µm.

2. The rocker arm according to claim 1, wherein the outer compound zone (7) has a thickness within a range of 10–20 µm.

3. The rocker arm according to claim 1 or 2, wherein a diffusion zone (8) with an inward gradually decreasing hardness is formed between the outer compound zone (7) and the steel matrix (9), said diffusion zone (8) having a thickness within a range of 50–800 µm.

4. The rocker arm according to claim 3, wherein the diffusion zone (8) has a thickness within a range of 100–400 µm.

5. A rocker arm assembly comprising a support shaft (2) and at least one rocker arm (1) according to any one of the preceding

claims, wherein the rocker arm (1) is configured to be rotatably mounted around the support shaft (2).

6. The rocker arm assembly according to claim 5, wherein the outer surface (3) of the bearing surface zone (4) of the at least one rocker arm (1) is in rotational contact with a peripheral surface (6) of the support shaft (2).

7. The rocker arm assembly according to claim 5 or 6, wherein the support shaft (2) is manufactured from cast iron.

8. The rocker arm assembly according to claim 7, wherein the cast iron is in the form of ductile cast iron.

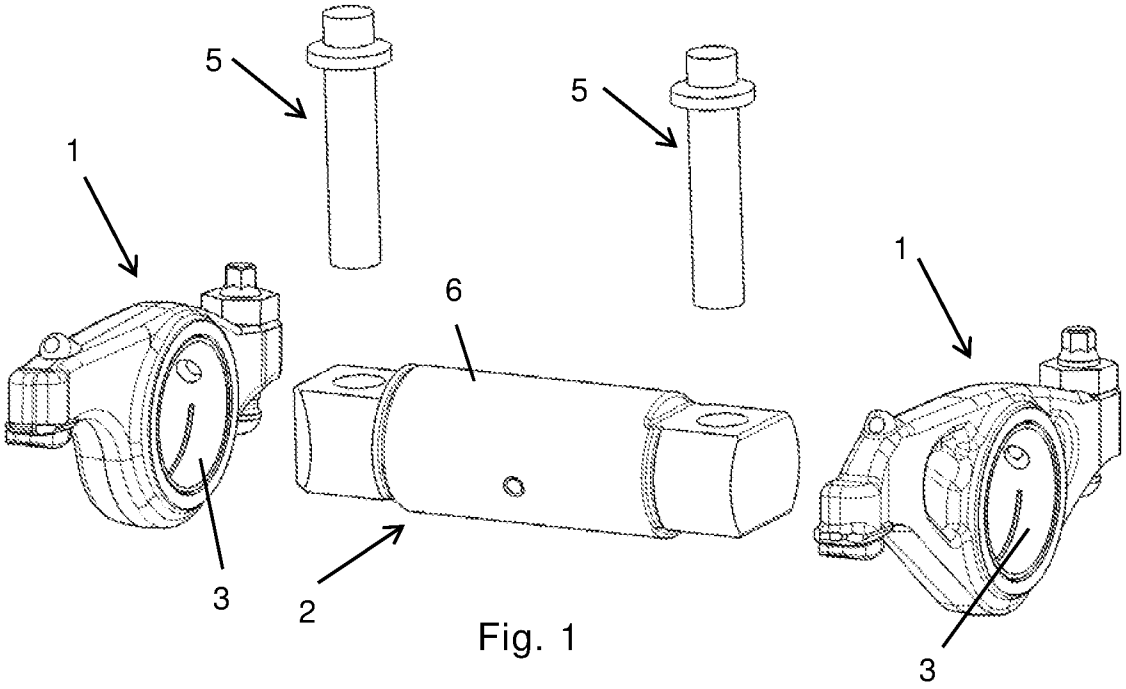

Fig. 1

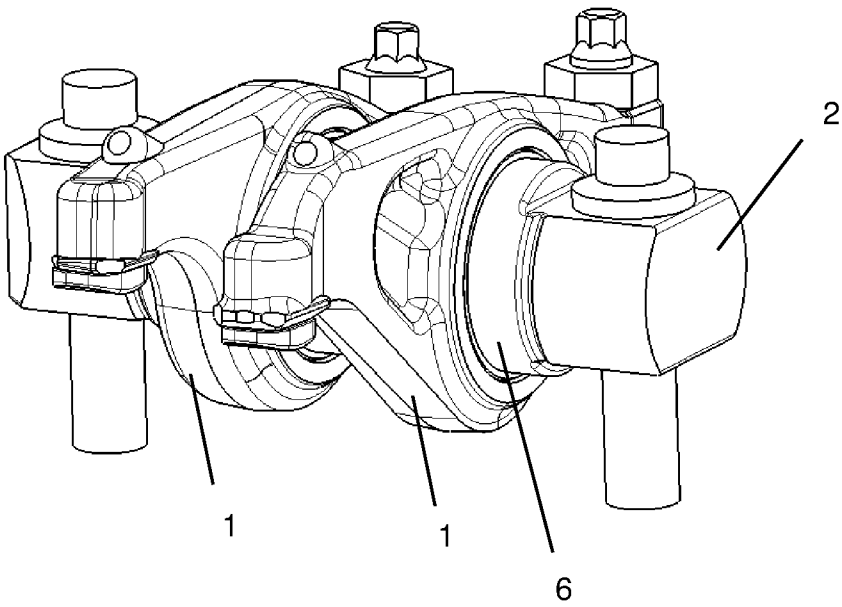

Fig. 2

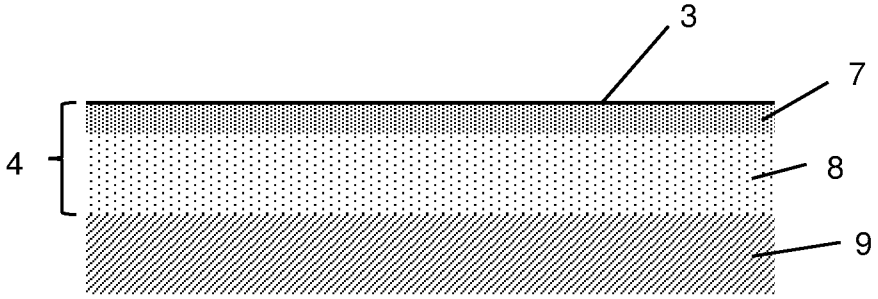

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: C21D, C23C, F01L

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5575064 A (FUJIWARA AKIRA ET AL), 19 November 1996 (1996-11-19); abstract; column 2, line 38 - column 2, line 45; claim 1	1-8
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A	Stål och Värmebehandling, En handbok, Swerea IVF, 2010 s. 481-482, 488-491, ISBN 978-91-86401-04-7; whole document	1-8
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A	DE 4205647 A1 (SCHAEFFLER WAELZLAGER KG), 26 August 1993 (1993-08-26); abstract	1-8
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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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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search	Date of mailing of the international search report
26-09-2016	26-09-2016

Name and mailing address of the ISA/SE	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/050601

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 09125916 A (RIKEN KK), 13 May 1997 (1997-05-13); (abstract) Retrieved from: EPODOCdatabase; Original document: --	1-8
A	JP 06220573 A (NIPPON PISTON RING CO LTD), 9 August 1994 (1994-08-09); (abstract) Retrieved from: EPODOC database; Original document: --	1-8
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Continuation of: second sheet

International Patent Classification (IPC)

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C23C 8/56 (2006.01)
F01L 1/18 (2006.01)

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