(51) International Patent Classification:
F02N 11/00 (2006.01)

(21) International Application Number:
PCT/US2010/053329

(22) International Filing Date:
20 October 2010 (20.10.2010)

(25) Filing Language: English

(26) Publication Language: English

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(54) Title: INTERNAL COMBUSTION ENGINE INCLUDING CRANKSHAFT THAT IS ROTATED WHILE ENGINE IS IN A NON-FUELED MODE AND METHOD OF OPERATING AN ENGINE


Declarations under Rule 4.17:

(Continued on next page)

(57) Abstract: A method of operating an engine includes starting and stopping operation of an internal combustion engine that includes a crankshaft having a bearing journal and a bearing in which the bearing journal is rotatable. The crankshaft is constantly turned when the internal combustion engine is in the non-fueled mode. An oil pump can be driven to lubricate the bearing journal and the bearing while the internal combustion engine is in the non-fueled mode to provide hydrodynamic lubrication. An engine is also disclosed.
— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(iii))
— of inventorship (Rule 4.17(iv))
BACKGROUND AND SUMMARY

[0001] The present invention relates to internal combustion engines and more particularly to crankshafts associated with such engines.

[0002] Repeated starting and stopping of an internal combustion engine results in substantial wear of crankshaft journals and journal bearings because the engine is not properly lubricated when rotation of the crankshaft starts. Journal bearings are ordinarily designed for full hydrodynamic lubrication. In other words, the crankshaft journal and the crankshaft journal bearings usually never make contact when the engine is running because there is a hydrodynamic oil film between them that prevents metal to metal contact. However, hydrodynamic lubrication requires oil pressure and shaft rotation. Oil pressure alone does not produce hydrodynamic lubrication but only boundary lubrication. In boundary lubrication there may be metal to metal contact and wear will occur. The inventors have recognized that, to provide hydrodynamic lubrication of a crankshaft journal and bearing arrangement, there must be both oil pressure and rotation of the crankshaft.

[0003] According to an aspect of the present invention, a method of operating an engine comprises switching the engine between being fueled and in a non-fueled mode, the internal combustion engine comprising a crankshaft having a bearing journal and a bearing in which the bearing journal is rotatable, and constantly turning the crankshaft when the internal combustion engine is in the non-fueled mode.
According to another aspect of the present invention, an engine comprises an internal combustion engine comprising a crankshaft having a bearing journal and a bearing in which the bearing journal is rotatable, and means for constantly turning the crankshaft when the internal combustion engine is in a non-fueled mode.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention are well understood by reading the following detailed description in conjunction with the drawings in which like numerals indicate similar elements and in which:

FIG. 1 is a schematic view of a hybrid engine according to an aspect of the present invention; and
FIG. 2 is a schematic view of another engine according to an aspect of the present invention.

DETAILED DESCRIPTION

An engine 21 according to an aspect of the present invention is shown in FIG. 1. The engine 21 includes an internal combustion engine 23 and comprises a crankshaft 25 having a bearing journal 27 and a bearing 29 in which the bearing journal is rotatable. An arrangement is provided for constantly turning the crankshaft 25 when the internal combustion engine 23 is in a non-fueled mode. For purposes of the present application, a "non-fueled mode" includes conditions when the internal combustion engine does not drive the crankshaft, usually when the internal combustion engine is not fueled, but not necessarily exclusively. The arrangement will ordinarily turn the crankshaft 25 through a complete rotation, however, the crankshaft can,
alternatively, be turned through less than 360° and merely pivot or rock back and forth which, all
of which motions shall, for purposes of the present application, be referred to genetically as
turning, except where otherwise indicated.

[0009] According to an aspect of the present invention, the engine 21 is a hybrid engine that also
comprises an electric motor 31, which is preferably a motor-generator. The electric motor 31
can be used to turn the crankshaft 25 when the internal combustion engine 23 is in the non-fueled
mode. A mechanical connection 33 (shown in phantom) to the crankshaft 25 can be provided,
such as a belt or gears between a driven shaft 35 of the electric motor 31 and the crankshaft.
Alternatively, another arrangement can be provided for turning the crankshaft 25, such as, in a
hybrid engine, a second electric motor 37 (shown in phantom) powered by a power source such
as a battery 39. The battery 39 can store energy from the motor-generator 31 and a controller 40
can be provided for controlling operation of the second motor 37 and/or the motor-generator.

[0010] Where the engine 21 is not a hybrid engine, as seen in FIG. 2, the crankshaft 25' can be
turned by any suitable means, such as an electric motor 37' or a mechanical arrangement such as
a spring that absorbs kinetic energy from stopping of a vehicle and releases it in a controlled
manner to turn the crankshaft when the internal combustion engine 23' is in the non-fueled
mode. Of course, any suitable means, not necessarily limited to the motor 31 or the motor 37,
can be used for turning the crankshaft 25 in the engine 21 of FIG. 1, as well.

[0011] Referring to FIG. 1, in addition to turning the crankshaft 25, it is desirable to maintain
hydrodynamic lubrication between the bearing journal 27 and the bearing 29 so that there is no
metal to metal contact and a film of lubricant such as oil remains between the journal and the
bearing. Hydrodynamic lubrication is achieved by constantly turning the crankshaft 25 and
providing lubricant such as oil under pressure to the bearing 29 and journal 27. Ordinarily, the
oil pump 41 of the internal combustion engine 23 is arranged to provide oil under pressure to the bearing journal 27 and the bearing 29 at all times. Accordingly, an arrangement is provided for driving the oil pump 41 while the internal combustion engine 23 is in the non-fueled mode. The arrangement may comprise, as shown in FIG. 1, a mechanical connection 43 (shown in phantom), such as a belt or gears, between the oil pump 41 and the crankshaft 25 such that turning of the crankshaft drives the oil pump. Alternatively, the oil pump 41 can be driven by an electrical drive such as by the electric motor 31 component of a hybrid engine, or a second electric motor 37, or by any other suitable electrical or non-electrical means.

[0012] In a method of operating an engine 21 according to an aspect of the present invention, the internal combustion engine 23 is periodically switched between being fueled and in a non-fueled mode, such as when it is desired to operate the electric motor 31 of a hybrid engine. The internal combustion engine 23 comprises the crankshaft 25 having the bearing journal 27 and the bearing 29 in which the bearing journal is rotatable. The crankshaft 25 is constantly turned, i.e., either by being pivoted or rocked back and forth or by being turned through 360°, when the internal combustion engine is in the non-fueled mode.

[0013] The oil pump 41 is driven to lubricate the bearing journal 27 and the bearing 29 while the internal combustion engine 23 is in the non-fueled mode. Ordinarily, the crankshaft 25 is turned while driving the oil pump 41 so as to maintain hydrodynamic lubrication between the bearing journal 27 and the bearing 29.

[0014] The crankshaft 25 can be turned and the oil pump 41 driven by any suitable means. For example, one or both of the crankshaft 25 and the oil pump 41 may be driven by the motor 31 of a hybrid engine 21, by a second motor 37 provided in addition to the hybrid engine motor, by an electric motor that is not part of a hybrid engine, by any other suitable driving means such as
springs, compressed gas, and the like. When used in vehicles, the means for driving the crankshaft will preferably be means that stores energy when the vehicle slows down, such as the motor-generator 31 of a hybrid engine. The oil pump 41 may, alternatively, be driven by means of a mechanical connection between the crankshaft 25 and the oil pump 41 when the crankshaft is driven by, for example, the motor-generator 31 or the motor 37.

[0015] In the present application, the use of terms such as "including" is open-ended and is intended to have the same meaning as terms such as "comprising" and not preclude the presence of other structure, material, or acts. Similarly, though the use of terms such as "can" or "may" is intended to be open-ended and to reflect that structure, material, or acts are not necessary, the failure to use such terms is not intended to reflect that structure, material, or acts are essential. To the extent that structure, material, or acts are presently considered to be essential, they are identified as such.

[0016] While this invention has been illustrated and described in accordance with a preferred embodiment, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.
WHAT IS CLAIMED IS:

1. A method of operating an engine, comprising:
   
   switching an internal combustion engine between being fueled and in a non-fueled mode,
   
   the internal combustion engine comprising a crankshaft having a bearing journal and a bearing in
   
   which the bearing journal is rotatable; and
   
   constantly turning the crankshaft when the internal combustion engine is in the non-fueled mode.

2. The method as set forth in claim 1, comprising turning the crankshaft through less than 360° when the internal combustion engine is in the non-fueled mode.

3. The method as set forth in claim 1, comprising rotating the crankshaft constantly when the internal combustion engine is in the non-fueled mode.

4. The method as set forth in claim 1, comprising driving an oil pump to lubricate the bearing journal and the bearing while the internal combustion engine is in the non-fueled mode.

5. The method as set forth in claim 4, wherein the oil pump is mechanically connected to the crankshaft so that rotation of the crankshaft drives the oil pump.

6. The method as set forth in claim 4, wherein the oil pump is electrically driven.
7. The method as set forth in claim 4, comprising rotating the crankshaft while driving the oil pump so as to maintain hydrodynamic lubrication between the bearing journal and the bearing.

8. The method as set forth in claim 1, wherein the internal combustion engine is part of a hybrid engine, the method comprising rotating the crankshaft via a mechanical connection to an electric motor of the hybrid engine.

9. The method as set forth in claim 8, comprising rotating the crankshaft via a second electric motor powered by a battery.

10. The method as set forth in claim 1, comprising rotating the crankshaft via an electric motor powered by a battery.

11. An engine, comprising:

   an internal combustion engine comprising a crankshaft having a bearing journal and a bearing in which the bearing journal is rotatable; and

   means for constantly turning the crankshaft when the internal combustion engine is in a non-fueled mode.

12. The engine as set forth in claim 11, wherein the engine is a hybrid engine comprising an electric motor, the rotating means comprises a mechanical connection to the electric motor.
13. The engine as set forth in claim 12, wherein the rotating means comprises a second electric motor powered by a battery.

14. The engine as set forth in claim 11, wherein the rotating means comprises an electric motor powered by a battery.

15. The engine as set forth in claim 11, comprising an oil pump arranged to lubricate the bearing journal and the bearing.

16. The engine as set forth in claim 15, comprising means for driving the oil pump while the internal combustion engine is in the non-fueled mode.

17. The engine as set forth in claim 16, wherein the driving means comprises a mechanical connection between the oil pump and the crankshaft such that rotation of the crankshaft drives the oil pump.

18. The engine as set forth in claim 16, wherein the driving means comprises an electrical drive.

19. The engine as set forth in claim 16, wherein the crankshaft is rotated and the oil pump is driven so as to maintain hydrodynamic lubrication between the bearing journal and the bearing.
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/053329

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F02N 11/00 (2010.01)
USPC - 123/179.1

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

B. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
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<th>Relevant to claim No.</th>
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<tr>
<td>X</td>
<td>WO 93/03275 A1 (SCHWARZ) 18 February 1993 (18.02.1993) entire document</td>
<td>1-4, 6, 7, 11, 15, 16, 18, 19</td>
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<td>Y</td>
<td>US 5,495,833 A (ISHIZAKA et al) 05 March 1996 (05.03.1996) entire document</td>
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<td>Y</td>
<td>US 2001/0018903 A1 (HIROSE et al) 06 September 2001 (06.09.2001) entire document</td>
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Date of the actual completion of the international search
06 December 2010

Date of mailing of the international search report
13 DEC 2010

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Form PCT/ISA/210 (second sheet) (July 2009)