Title of the Invention: **Power unit for a hybrid electric vehicle**

Abstract Title: **Power unit for a hybrid electric vehicle**

A power unit for a hybrid electric vehicle comprising an internal combustion engine with an output shaft having a first rotary device mounted on a first side of the axis of rotation of the output shaft and a second rotary device mounted on a second side of the axis of rotation of the output shaft of the internal combustion engine. Each of the rotary devices having a respective rotor shaft disposed parallel to the output shaft and being mechanically coupled to the output shaft for transmitting torque between the respective rotor shaft and the output shaft of the engine. One or both of the rotary devices may be electric motor generators or one or both may be hydraulic machines such as fluid pumps. The rotary devices may be located symmetrically about a vertical plane that is aligned with the axis of the cylinders within the engine and may be coupled to the output shaft via endless drive members (belts) disposed parallel to the output shaft. The devices may be pivotally coupled and a tensioner may equably bias each device to maintain tension in the respective drive member.
FIELD OF THE INVENTION

This invention relates to a power unit for a hybrid electric vehicle, in particular a commercial vehicle, such as a bus.

BACKGROUND OF THE INVENTION

Hybrid Electric Vehicles (HEVs) combines a conventional internal combustion engine propulsion system with an electric propulsion system. Typically HEVs use their internal combustion engine to drive an electrical generator, generating electricity to either recharge batteries or to directly power one or more electric drive motors. HEVs typically make use of efficiency-improving technologies such as regenerative brakes, whereby a vehicle's kinetic energy is converted into electric energy by driving an electrical generator, rather than wasting it as heat energy as conventional brakes do. It is also known to reduce vehicle emissions by shutting down the internal combustion engine at idle and restarting it when needed. This is known as a start-stop system. Often the electrical generator is also used as a motor to start and/or drive the internal combustion engine, as a starter motor and/or to supplement the power supplied by the internal combustion engine. This type of generator is typically referred to as a motor generator.

Particularly in lower voltage systems, such as 48 volt systems, the internal combustion engine drives the drive wheels of the vehicle via a gearbox and a motor generator is used to supplement the power supplied by the internal combustion engine, to start the engine and to generate electricity to charge the batteries, particularly during regenerative braking. This arrangement is often referred to as a "micro-hybrid" vehicle.

Typically such motor generators are driven from the output shaft of the internal combustion engine via a drive belt running around pulleys on the rotor shaft of the motor generator and on the output shaft of the internal combustion engine, said drive belt also typically driving other ancillary components, such as power steering
and air conditioning pumps. This allows the motor generator to spin faster than the output shaft of the internal combustion engine by the use of suitably sized pulleys.

However, such drive belts can require complex tensioning arrangements required to allow the motor generator to both drive and be driven by the internal combustion engine, whereby the tension on either side of the drive belt varies. Also, such motor generators, particularly where large output devices are used, require considerable belt tension to prevent belt slippage under load. This can place excessive lateral loadings on the output shaft of the engine.

Typically the crankshaft of an internal combustion engine runs on plain bearings which rely on engine oil pressure to avoid metal on metal contact. Such bearings are extremely intolerant to loadings extending parallel to the join line of the two halves of the bearing, typically arranged in a horizontal plane to the usual vertical alignment of the cylinders of the internal combustion engine. This is a particular problem during engine start up when the oil pressure may be low. However, space requirement typically dictate that the motor generator be laterally spaced to one side of the output shaft of the engine, thus limiting the size of the motor generator that may be used.

This is not such a problem in small automobiles, with relatively small output petrol engines and correspondingly small output motor generators. However, in commercial vehicles where larger diesel engines are typically used the size requirements of the motor generator and thus the belt tension required to prevent slippage can lead to the imposition of excessive lateral forces on the output shaft of the internal combustion engine.

An object of the present invention is to provide a power unit for a hybrid electric vehicle, in particular a commercial vehicle such as a bus, that overcomes the abovementioned problem.

SUMMARY OF THE INVENTION
According to the present invention there is provided a power unit for a hybrid electric vehicle comprising an internal combustion engine having an output shaft with an axis of rotation, a first rotary device mounted on a first side of the axis of rotation of the output shaft of the internal combustion engine, a second rotary device mounted on a second side of the axis of rotation of the output shaft of the internal combustion, opposite said first side, each of said first and second rotary devices having a respective rotor shaft disposed parallel to the output shaft of said engine and being mechanically coupled to the output shaft of said internal combustion engine for transmitting torque between the respective rotor shaft and the output shaft of the engine.

Preferably the first and second rotary devices are arranged symmetrically on either side of the output shaft of the internal combustion engine. In one embodiment, wherein the cylinders of the engine are arranged, in use, substantially vertically, said first and second rotary devices may be arranged substantially symmetrically about a vertical plane aligned with the axis of rotation of the output shaft of the internal combustion engine. In one embodiment the first and second rotary devices may be arranged substantially symmetrically about the axis of at least one cylinder of the internal combustion engine.

The rotor shaft of each of said first and second rotary devices is preferably coupled to the output shaft of said internal combustion engine by a respective endless drive member. A tensioning device is preferably provided acting between the endless drive members for tensioning each of said endless drive members by equal amounts, minimising the side loading on the output shaft of the internal combustion engine.

In one embodiment each of said first and second rotary devices is pivotally mounted on the internal combustion engine about a respective pivot axis perpendicular to and laterally spaced from a line extending through the axis of the output shaft of the engine and the axis of the rotor shaft of the respective rotary device and parallel to the axis of the output shaft such that pivotal movement of the respective rotary device with respect to the engine varies the distance between the rotor shaft of the respective rotary device and the output shaft of the engine, said tensioning device
acting between the rotary devices to tension the endless drive members. Said
tensioning device may comprise a variable length strut extending between the
rotary devices.

In one embodiment said strut may incorporate biasing means biasing the strut
towards a fully extended position to apply a resilient biasing force to the respective
rotary devices about the respective pivot axis thereof in a direction away from the
output shaft of the engine. Said biasing means may comprise a spring or a piston
disposed in a cylinder containing a pressurised fluid.

At least one of said first and second rotary devices may comprise a motor
generator. In one embodiment both of said first and second rotary devices
comprise motor generators, preferably comprising identical devices.

In an alternative embodiment at least one of said first and second rotary devices
comprises a hydraulic machine, such as a fluid pump.

Preferably said internal combustion engine comprises a diesel engine.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a power unit for a hybrid electric commercial
vehicle in accordance with a first embodiment of the present invention; and

Figure 2 is an end view of the power unit of Figure 1.

DETAILED DESCRIPTION OF THE DRAWINGS

As shown in the drawings, a power unit for a hybrid electric commercial vehicle in
accordance with an embodiment of the present invention comprises an internal
combustion engine 2 wherein an output shaft 4 of the engine 2 is mechanically
coupled to a pair of motor generators 6,8 both for generating electricity and for
driving the internal combustion engine 2. The internal combustion engine may
comprise a four cylinder diesel engine of around 4 litre capacity, for example for use
in a commercial vehicle, more particularly a lightweight bus, such as the Wrightbus StreetLite 40 seat range. However, other engine configurations and sizes, fuelled by diesel, petrol or lpg, for numerous other applications, are envisaged.

The lightweight bus market is becoming increasingly popular due to flexibility and low running costs compared to a large double deck bus. By incorporating hybrid electric technology, lightweight diesel buses can achieve low carbon emission bus accreditation, often required for city centre use. In what is often referred to as a "micro-hybrid", the internal combustion engine is coupled to a motor generator which charges the batteries during braking to power auxiliaries, delivering a significant fuel saving, while acting as a starter motor for engine starting, facilitating the use of stop start technology, and supplementing the power of the internal combustion engine when required, for example to mitigate turbo lag, without the extra costs associated with a full hybrid vehicle's complexity and batteries (i.e. where electric motors drive the vehicle and the internal combustion engine is used solely to charge batteries). However, as discussed above, the use of a single relatively large motor generator coupled to the output shaft of the internal combustion engine by a belt drive can place an excessive lateral load on the output shaft.

The power unit in accordance with the present invention solves this problem by utilising two smaller motor generators 6,8 instead of one larger motor generator and by locating the two motor generators 6,8 symmetrically on either side of the output shaft 4 of the internal combustion engine 2. The motor generators 6,8 may be driven by respective drive belts 10,12 that are linked by a common tensioner arrangement that substantially balances the tension of each belt 10,12 and thus the lateral forces applied to the output shaft 4 of the internal combustion engine by the two motor generators 6,8. Each drive belt 10,12 passes around a respective pulley 14,16 mounted on the rotor shaft 18,20 of the respective motor generator 6,8 and a pulley 18 mounted on the output shaft 4 of the internal combustion engine 2. It is envisaged that other drive means may be used for transferring drive between the motor generators and the engine, for example chains and sprockets or gearing or hydraulic motors/pumps.
As shown in the drawings, in a preferred embodiment each motor generator 6,8 is pivotally mounted onto the block of the internal combustion engine 2 at an upper side of each motor generator 6,8, above the respective rotor shaft thereof, for pivotal movement about an axis extending parallel to the output shaft 4 of the engine 2. Such pivotal mounting of the motor generators 6,8 on the engine 2 allows the tension of each drive belt 10,12 to be adjusted by pivotally moving the respective motor generator 6,8 with respect to the engine 2, thus adjusting the distance between the rotor shaft of the respective motor generator 6,8 and the output shaft 4 of the internal combustion engine 2.

In order to adjust and maintain the tension the drive belts 10,12, a variable length elongate strut 20 may be mounted between the motor generator 6,8, the ends of the strut 20 being pivotally coupled to the motor generators 6,8, below the rotor shaft of the respective motor generator 6,8 and adjacent a lower side thereof whereby the length of the strut 20 can be adjusted to adjust the tension on the drive belts 10,12. By coupling the two motor generators 6,8 in this way the tension on the drive belt 10,12 is balanced/equalised, thus minimising any resultant lateral loading on the output shaft 4 of the internal combustion engine 2.

In the embodiment shown in the drawings, the length of the strut 20 is adjusted by the use of rose joints 22,24 which are screwed into threaded holes in each end of the strut 20 and by means of which the ends of the strut 20 are pivotally mounted to the motor generators.

In an alternative embodiment, the strut 20 may be biased towards an extended position, displacing the rotor shaft of each motor generator away from the output shaft 4 of the internal combustion engine and tensioning the drive belts 10,12, by biasing means, such as a compression spring, or via hydraulic tensioning means, such as a piston moveable in a cylinder containing a pressurised fluid, such as engine oil pressurised by an oil pump of the engine 2.

In the embodiment shown in the drawings, the rotor shafts of the motor generators 6,8 are located in a plane located slightly below the axis of rotation of the output shaft 4 of the engine 2. This will result in a small resultant radial loading on the
output shaft in a downwards direction. However, this will be well within the acceptable lateral loading tolerance of the main bearings of the crankshaft of the internal combustion engine 2, particularly since such bearings are normally split horizontally and thus are tolerant to vertical loads perpendicular to the split line of the bearings. However, it is envisaged that the rotor shafts of the motor generators 6,8 may be aligned with the output shaft 4 of the engine in a substantially horizontal plane should it be desired to minimise the resultant sideways load on the output shaft 4 of the engine 2.

While the invention has been described in relation to the use of paired motor generators, it is envisaged that other rotary machine may be provided in place of one or both of the motor generators, for example hydraulic machines, such as fluid pumps and/or hydraulic motors.

By coupling the motor generators 6,8 to the engine 2 in this way, using drive belts 10,12 with balanced tensioning, the motor generators 6,8 can be readily used for starting the engine (in start/top functionality), boosting engine power when required, regenerative braking and efficient electricity generation for battery charging and powering ancillary components of the vehicle in which the power unit is installed, without placing excessive lateral loading on the output shaft 4 of the internal combustion engine 2 and thus enabling the implementation of hybrid electric vehicle technology without substantial modification to the internal combustion engine or the vehicle.

The invention is not limited to the embodiment(s) described herein but can be amended or modified without departing from the scope of the present invention.
CLAIMS

1. A power unit for a hybrid electric vehicle comprising an internal combustion engine having an output shaft with an axis of rotation, a first rotary device mounted on a first side of the axis of rotation of the output shaft of the internal combustion engine, a second rotary device mounted on a second side of the axis of rotation of the output shaft of the internal combustion, opposite said first side, each of said first and second rotary devices having a respective rotor shaft disposed parallel to the output shaft of said engine and being mechanically coupled to the output shaft of said internal combustion engine for transmitting torque between the respective rotor shaft and the output shaft of the engine.

2. A power unit as claimed in claim 1, wherein the first and second rotary devices are arranged symmetrically on either side of the output shaft of the internal combustion engine.

3. A power unit as claimed in claim 2, wherein said first and second rotary devices are arranged substantially symmetrically about a vertical plane aligned with the axis of rotation of the output shaft of the internal combustion engine.

4. A power unit as claimed in claim 2 or claim 3, wherein the internal combustion engine has at least one cylinder, said first and second rotary devices being arranged substantially symmetrically about the axis of said cylinder.

5. A power unit as claimed in any of claims 1 to 4, wherein the rotor shaft of each of said first and second rotary devices is coupled to the output shaft of said internal combustion engine by a respective endless drive member.

6. A power unit as claimed in claim 5, wherein a tensioning device is provided acting between the endless drive members for tensioning each of said endless drive members by equal amounts, minimising the side loading on the output shaft of the internal combustion engine.
7. A power unit as claimed in claim 6, wherein each of said first and second rotary devices is pivotally mounted on the internal combustion engine about a respective pivot axis perpendicular to and laterally spaced from a line extending through the axis of the output shaft of the engine and the axis of the rotor shaft of the respective rotary device and parallel to the axis of the output shaft such that pivotal movement of the respective rotary device with respect to the engine varies the distance between the rotor shaft of the respective rotary device and the output shaft of the engine, said tensioning device acting between the rotary devices to tension the endless drive members.

8. A power unit as claimed in claim 7, wherein said tensioning device comprises a variable length strut extending between the rotary devices.

9. A power unit as claimed in claim 8, wherein said strut incorporates biasing means biasing the strut towards a fully extended position to apply a resilient biasing force to the respective rotary devices about the respective pivot axis thereof in a direction away from the output shaft of the engine.

10. A power unit as claimed in claim 9, wherein said biasing means comprises a spring.

11. A power unit as claimed in claim 10, wherein said biasing means comprises a piston disposed in a cylinder containing a pressurised fluid.

12. A power unit as claimed in any preceding claim, wherein at least one of said first and second rotary devices comprises a motor generator.

13. A power unit as claimed in claim 12, wherein both of said first and second rotary devices comprise motor generators.

14. A power unit as claimed in any of claims 1 to 12, wherein at least one of said first and second rotary devices comprises a hydraulic machine.
15. A power unit as claimed in claim 14, wherein said hydraulic machine comprises a fluid pump.

16. A power unit as claimed in any preceding claim, wherein said internal combustion engine comprises a diesel engine.

17. A commercial vehicle incorporating a power unit as claimed in any preceding claim.

18. A commercial vehicle as claimed in claim 17, wherein said vehicle comprises a bus.

19. A power unit for a hybrid electric vehicle substantially as herein described with reference to the accompanying drawings.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<th>Category</th>
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<td>X</td>
<td>1-6, 12, 13 &amp; 16-18</td>
<td>US2012/0152644 A1 (KYDD II) See particularly the figures.</td>
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<tr>
<td>X</td>
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<td>EP1132245 A2 (HIROSE) See particularly figure 2 and the accompanying description.</td>
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<td>JP2011011573 A (ODAGIRI) See particularly figure 3 and the accompanying description.</td>
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<tr>
<td>X</td>
<td>1, 12 &amp; 14-18</td>
<td>JP2001107827 A (MORIYA) See particularly figure 1 and the accompanying description.</td>
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<td>X</td>
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<td>WO03/038309 A1 (ALEXANDER) See particularly figures 1 and 3.</td>
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<tr>
<td>X</td>
<td>1, 12, 13, 16 &amp; 17</td>
<td>US2002/0036106 A1 (HANYU) See figures 1, 2 and 6 and the description, particularly paragraphs 45 and 59.</td>
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Categories:

- X Document indicating lack of novelty or inventive step
- Y Document indicating lack of inventive step if combined with one or more other documents of same category
- & Member of the same patent family
- A Document indicating technological background and/or state of the art.
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Field of Search:
Search of GB, EP, WO & US patent documents classified in the following areas of the UKCX:
Worldwide search of patent documents classified in the following areas of the IPC

B60K

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

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