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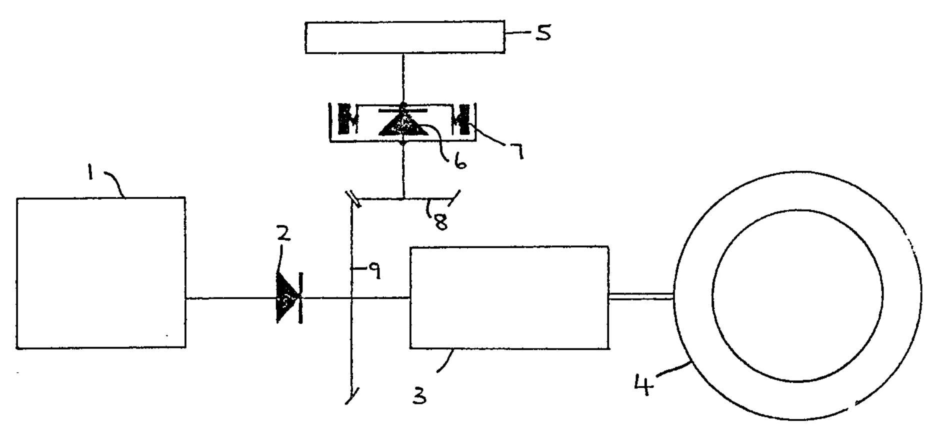
(54) Driveline for regenerative braking

(57) A diesel engine 1 drives a continuously-variable-ratio transmission 3 via an over-running clutch 2 and the transmission in turn drives a drive axle 4. A flywheel 5, used to store energy when the vehicle equipped with the driveline is braked, is energised via the transmission and also drives it when returning its stored energy to the vehicle.

The connection between the flywheel 5 and the transmission 3 is via an over-running clutch 6 and a centrifugal clutch 7. The centrifugal clutch closes at a speed which is such that the speed of the gear 9 is a little above the maximum speed it could be driven by the engine 1. When the flywheel 5 is not energised, the centrifugal clutch 7 is open and the engine 1 drives the transmission 3 via the clutch 2 and, after bringing the flywheel up to a speed corresponding to maximum engine speed, the flywheel is not driven so long as the engine speed is below maximum (because of clutch 6). When the flywheel 5 is energised during braking, the centrifugal clutch 7 is closed and the engine is decoupled from the transmission (because of clutch 2).

The transmission is thus driven either by the flywheel or by the engine, and switching between the two takes place automatically.



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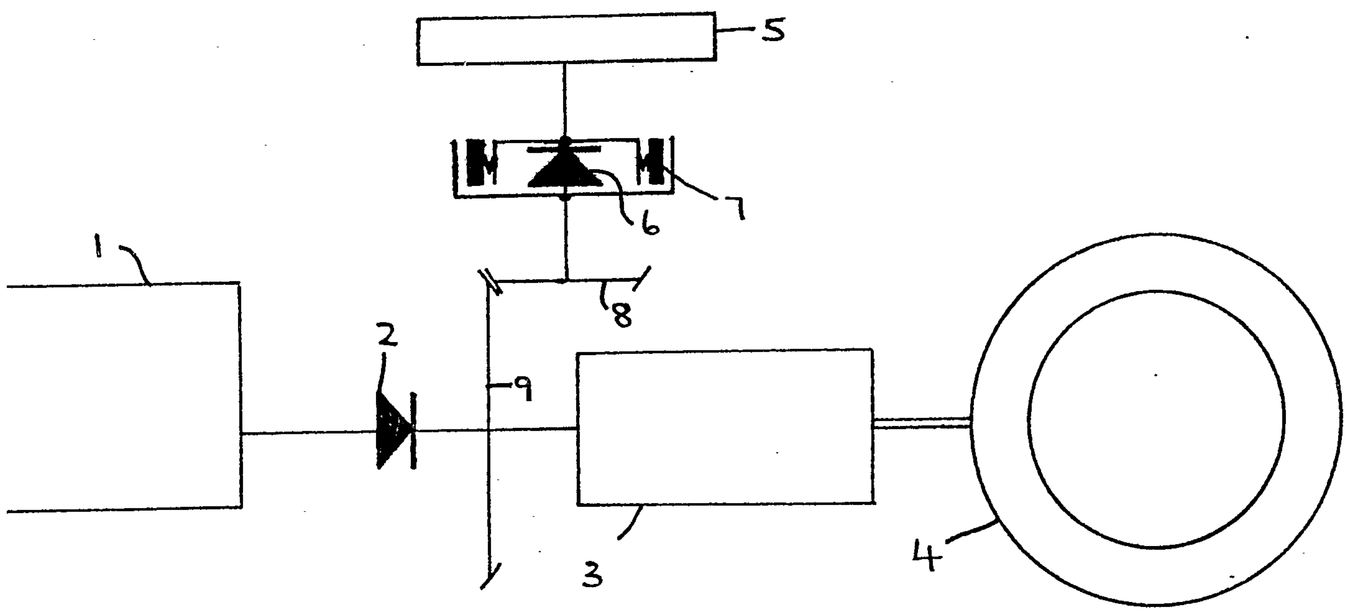
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SPECIFICATION

Driveline for regenerative braking

This invention relates to drivelines for regenerative braking, especially to those drivelines including continuously-variable-ratio transmissions.

Drivelines of this kind are known, but there are difficulties associated with the control of the engine and flywheel.

The invention provides a driveline which includes a continuously variable ratio transmission, an engine for driving the transmission, and a flywheel for driving the transmission which is itself driven by the transmission to brake the vehicle wherein the flywheel can only drive the transmission when the engine is not driving the transmission.

The fact that the transmission is driven either by the engine or by the flywheel, but not by both together, makes controlling the engine and flywheel simpler.

Advantageously, the flywheel can only drive the transmission at speeds in excess of those at which the engine can drive the transmission.

Advantageously, the engine is coupled to the transmission via an over-running clutch which is arranged to decouple when the speed on the transmission side exceeds that on the engine side, and the flywheel is connected to the transmission downstream of the over-running clutch in the drive direction.

The engine is coupled and decoupled automatically with this arrangement. The engine is automatically decoupled when the flywheel speed is in the range where it can drive the transmission and automatically recoupled when the flywheel can no longer provide drive.

Advantageously, the flywheel is coupled to the transmission via an over-running clutch which is arranged to decouple when the speed on the flywheel side exceeds that on the transmission side, and which is capable of being locked up when a certain flywheel speed is exceeded.

The flywheel thus couples in automatically for energisation but only becomes locked in for de-energisation at a certain speed. Preferably, a centrifugal clutch is provided in parallel with the flywheel over-running clutch in order to lock it up.

The engine could be spark ignition but is preferably compression ignition, and the continuously variable-ratio transmission could be of the pulley and belt type but is preferably of the toroidal race rolling friction type, where traction takes place through an elastohydrodynamic film.

A driveline constructed in accordance with the invention will now be described, by way of example, with reference to the accompanying drawing, which is a schematic view of the driveline.

Referring to the drawing, the driveline has a diesel engine 1 as prime mover which is coupled to a continuously-variable-ratio transmission 3 via a sprag over-running clutch 2. The continuously-variable-ratio transmission 3 drives a drive axle 4.

A flywheel 5 is provided for the purposes of regenerative braking. The flywheel is coupled to the input of the continuously-variable-ratio transmission downstream of the sprag clutch 2, and via a second sprag clutch 6 which is combined with a centrifugal clutch 7 and drive gears 8 and 9.

The sprag clutches 2 and 6 are arranged so that they over-run, respectively, when the speed of the transmission side 3 exceeds that on the engine side 1 and when the speed on the flywheel side 5 exceeds that on the drive gears 8, 9 side. The centrifugal clutch closes when the flywheel speed is greater than the speed the flywheel would have (allowing for the step-up of the gears 8, 9) if driven by the engine at its full speed.

The operation of the drive-train is as follows. When starting the engine of the vehicle with the flywheel 5 stationary, the flywheel 5 will be clutched into the engine from the start because of the sprag clutches 2 and 6. The engine is accelerated to its maximum speed, which will then be the minimum operational speed of the flywheel.

During subsequent driving of the vehicle, the flywheel 5 is decoupled provided the engine speed is less than its maximum value, and the vehicle can be driven in the same way as if the flywheel was not present. (The centrifugal clutch 7 is decoupled since it only engages at a speed above maximum engine speed). If the flywheel speed drops to below the engine maximum speed, it is accelerated again and becomes decoupled when the engine speed reduces.

Regenerative braking takes place by accelerating the flywheel 5, achieved by downshifting the transmission 3, and the energy of the vehicle is fed via the drive axle 4 along the transmission 3 from the output and to the input end. The input accelerates above the maximum engine speed, causing the engine sprag to freewheel, and the flywheel sprag 6 to couple. Regenerative braking now takes place.

When the flywheel accelerates to a particular value above that corresponding to maximum engine speed, the centrifugal clutch 7 closes.

The flywheel 5 is now locked into the driveline until it slows down to the value at which the centrifugal clutch opens. Since this value is above that corresponding to maximum engine speed, it follows that the engine is decoupled from the driveline during this time. The stored energy is now available for vehicle drive through the transmission 3.

As the flywheel 5 approaches the speed at which the centrifugal clutch 7 opens, the clutch will slip and the slow down of the input of the transmission 3 will increase. The engine must now be accelerated from idle to its required running speed, and the sprag clutch 2 will couple when the speed on the engine side equals that on the transmission input side. The engine is now available for normal drive. The drag torque produced by the slipping centrifugal clutch is used to bridge the switch from flywheel to engine power, and will disappear as it further slows the flywheel.

As an example of suitable speeds of operation the diesel engine may have a maximum speed of approximately 3000 rpm and the centrifugal clutch 7, which governs the speeds at which the flywheel can drive the transmission may close at a value such that the speed of drivegear 9 is within the range 3250 rpm to 3500 rpm. The maximum flywheel speed may be such that the speed of drivegear 9 is approximately 6000 rpm.

The minimum flywheel speed will be the maximum speed of the engine. If during long periods of engine only running the flywheel drops below this referred speed (referred speed being the speed at the drivegear 9) i.e. 3000 rpm, the engine accelerates to bring it back to 3000 rpm, this could be accomplished by means of a sensor on the flywheel.

However, if the engine was running at a low speed e.g. 1000 rpm, one could then face the problem that the engine would be continually speeding up to bring the flywheel to the referred speed of 3000 rpm and then dropping back, only to speed up again shortly when the flywheel dropped below 3000 rpm again. For this reason, the engine could be allowed an overspeed range, that is, it could speed up to 3250 rpm (with the centrifugal clutch operating now at 3500 rpm) to bring the flywheel to within its operational range, while still having a maximum speed of 3000 rpm if driving the engine only. This will of course ensure that the flywheel will be 'transparent' for all but very short periods.

With the above arrangement, the vehicle will be driven either by the flywheel or by the engine, and switching between the two is automatic.

If it is desired that the flywheel is not clutched in on start-up, for example, to prevent heavy loading on the starter motor, a disconnect clutch could be incorporated. The engine alone could be started on the starter motor, and the flywheel could be engaged with the engine idling. A dryplate clutch could be used as the disconnect clutch. As an alternative, the flywheel could be accelerated from rest before the engine is started by using an electric motor (which could be the starter motor). When the flywheel is running slightly faster than the value corresponding to engine idle speed, the engine is free to start without engaging the sprag clutches.

If desired, a release mechanism could be incorporated in the combined flywheel clutch in order to disconnect the fully energised flywheel. This would improve drive-line efficiency with the vehicle stationary.

If desired, the centrifugal clutch could be dispensed with and any clutch (such as a multiplate electrically controlled clutch) could replace it, the clutch being arranged in parallel with the over-running clutch 6 to lock it up over the desired speed range.

Also, the flywheel could be arranged to drive the steering pump, compressors for a brake pump, air compressor for power operated doors, or other ancilliaries normally driven by the engine.

The transmission is preferably a toroidal race rolling friction type. Reduction gears may be required at its input to restrict the maximum speed at the input.

The driveline of the invention is suited to use in heavy goods vehicles, where the braking energies are appreciable, and especially to use in public service vehicles (that is, buses) where a lot of stopping and starting is involved.

Claims

1. A driveline which includes a continuously-variable ratio transmission, an engine for driving the transmission, and a flywheel for driving the transmission which is itself driven by the transmission to brake the vehicle, wherein the flywheel can only drive the transmission when the engine is not driving the transmission.

2. A driveline as claimed in claim 1, wherein the flywheel can only drive the transmission at speeds in excess of those at which the engine can drive the transmission.

3. A driveline as claimed in claim 1 or claim 2, wherein the engine is coupled to the transmission via an over-running clutch which is arranged to decouple when the speed on the transmission side exceeds that on the engine side, and the flywheel is connected to the transmission downstream of the over-running clutch in the drive direction.

4. A driveline as claimed in any one of claims 1 to 3 wherein the flywheel is coupled to the transmission via an over-running clutch which is arranged to de-couple when the speed on the flywheel side exceeds that on the transmission side, and which is capable of being locked up when a certain flywheel speed is exceeded.

5. A driveline as claimed in claim 4, wherein a centrifugal clutch is provided in parallel with the fly-wheel over-running clutch in order to lock it up.

6. A driveline as claimed in any one of claims 1 to 5 wherein the continuously-variable-ratio transmission is of the toroidal race rolling friction type.

7. A driveline substantially as hereinbefore described with reference to, and as shown in the accompanying drawings.

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