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(54) Abstract Title

IC engine net torque calculator

(57) The net torque produced by an ic engine is determined as the difference between the gross torque generated and the internal and external torque losses. Gross torque is estimated 2 in accordance with the amount of fuel injected 6.

Internal engine torque losses due to friction are estimated 19 according to engine speed and coolant temperature and external torque losses are estimated 17 depending upon the auxiliary equipment being driven eg air conditioning units. An expected torque loss correction 21 is determined from an adaptive look up table 20 and is dependent upon coolant temperature.

The estimated internal and external torque losses and the expected torque loss correction are summed 22,24 and subtracted 26 from the gross torque to produce an estimated net torque signal 1. When no power is being drawn by the gearbox the actual net torque is determined from the engine acceleration and the difference between the actual and estimated net torque is used to update the expected torque loss correction value in the adaptive look up table 20.

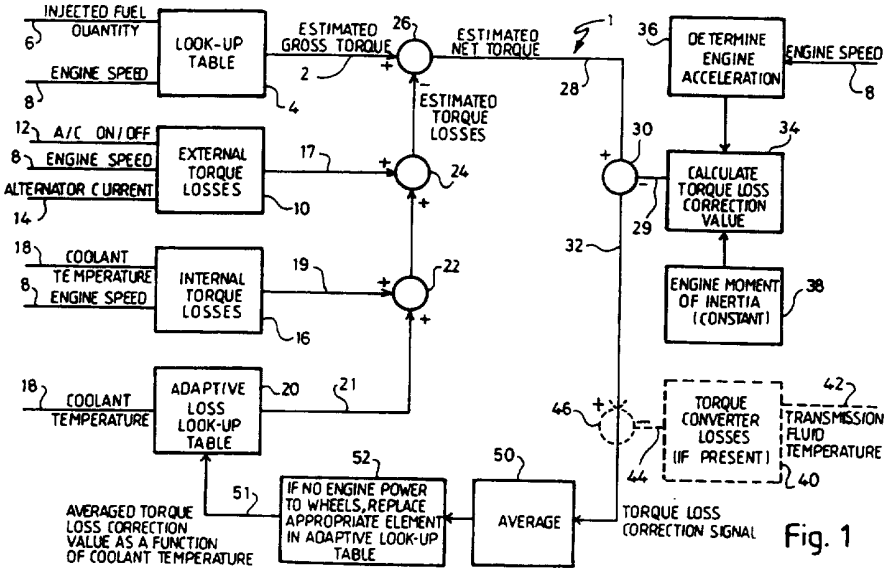

Fig. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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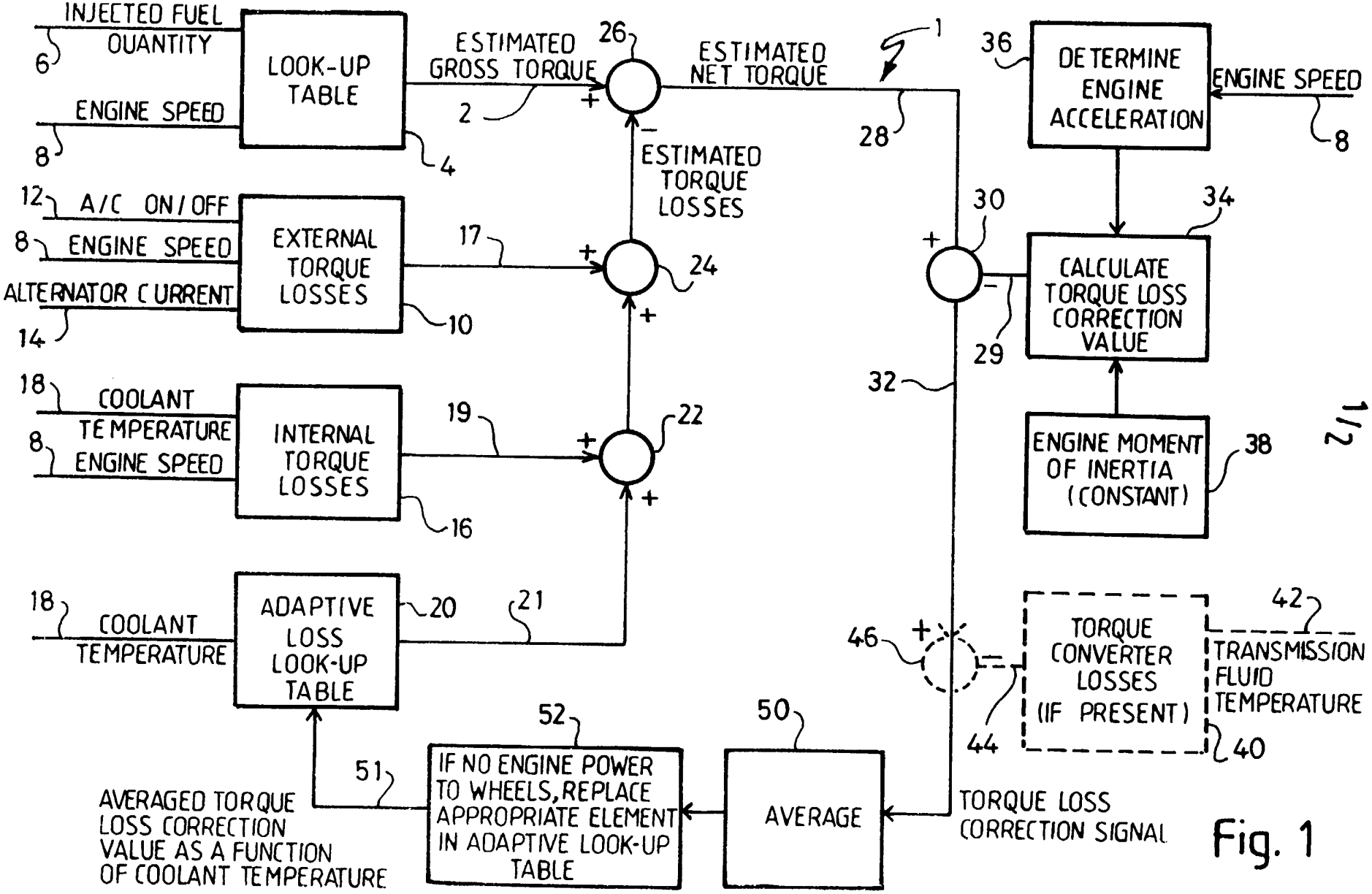
INJECTED FUEL QUANTITY
6
ENGINE SPEED
8
LOOK-UP TABLE
ESTIMATED GROSS TORQUE
2
4
26
ESTIMATED NET TORQUE
28
1
ESTIMATED TORQUE LOSSES
12
A/C ON/OFF
8
ENGINE SPEED
ALTERNATOR CURRENT
14
EXTERNAL TORQUE LOSSES
17
10
24
18
COOLANT TEMPERATURE
8
ENGINE SPEED
INTERNAL TORQUE LOSSES
19
16
22
18
COOLANT TEMPERATURE
ADAPTIVE LOSS LOOK-UP TABLE
20
21
36
DETERMINE ENGINE ACCELERATION
ENGINE SPEED
8
30
34
CALCULATE TORQUE LOSS CORRECTION VALUE
29
32
ENGINE MOMENT OF INERTIA (CONSTANT)
38
46
42
TORQUE CONVERTER LOSSES (IF PRESENT)
TRANSMISSION FLUID TEMPERATURE
44
40
52
50
51
IF NO ENGINE POWER TO WHEELS, REPLACE APPROPRIATE ELEMENT IN ADAPTIVE LOOK-UP TABLE
AVERAGE
AVERAGED TORQUE LOSS CORRECTION VALUE AS A FUNCTION OF COOLANT TEMPERATURE
TORQUE LOSS CORRECTION SIGNAL

Fig. 1

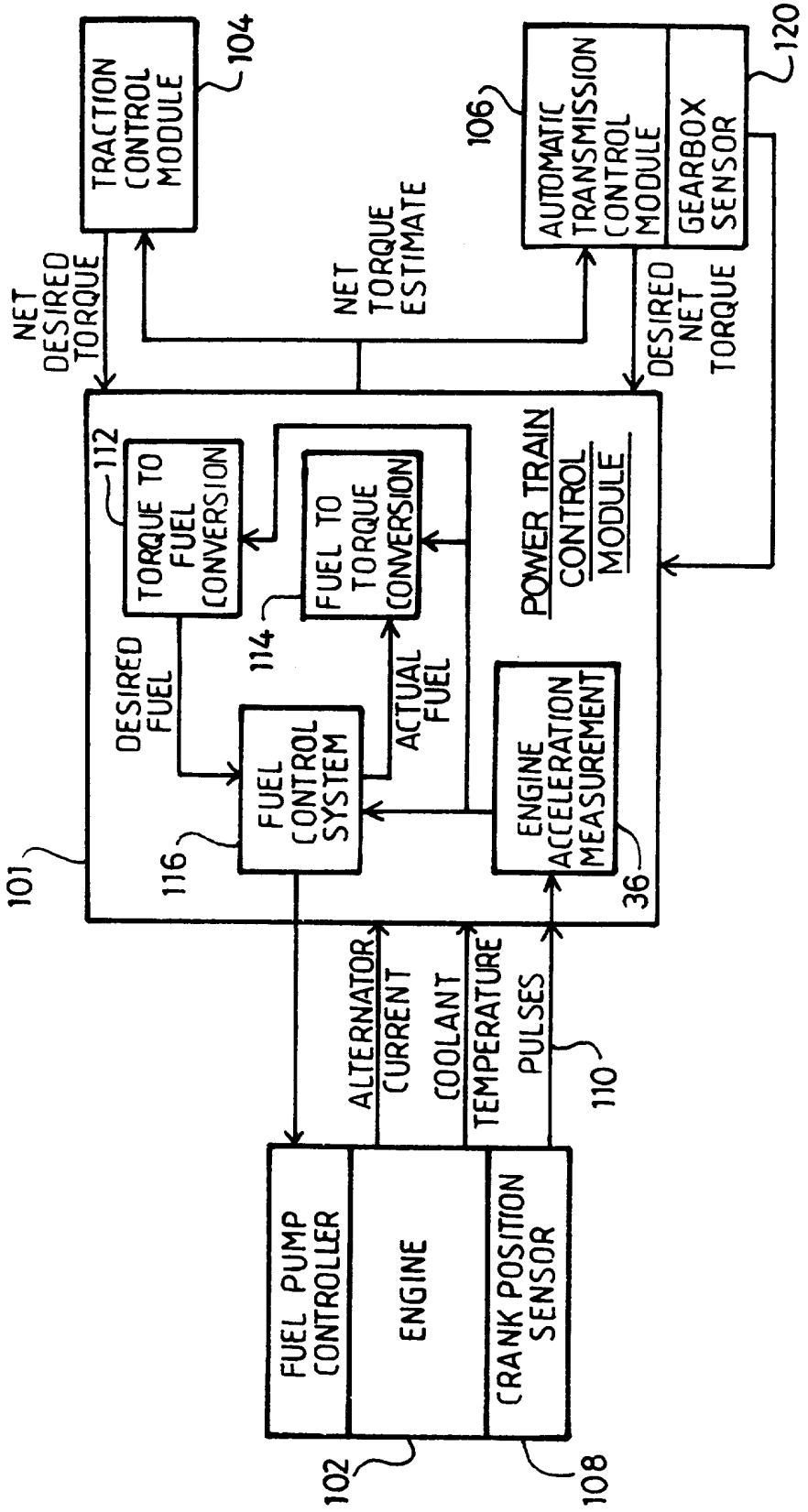
TRACTION CONTROL MODULE
104
AUTOMATIC TRANSMISSION CONTROL MODULE
106
GEARBOX SENSOR
120
NET DESIRED TORQUE
NET TORQUE ESTIMATE
DESIRED NET TORQUE
POWER TRAIN CONTROL MODULE
101
TORQUE TO FUEL CONVERSION
112
FUEL TO TORQUE CONVERSION
114
DESIRED FUEL
ACTUAL FUEL
FUEL CONTROL SYSTEM
116
ENGINE ACCELERATION MEASUREMENT
36
ALTERNATOR CURRENT
COOLANT TEMPERATURE
PULSES
110
FUEL PUMP CONTROLLER
ENGINE
CRANK POSITION SENSOR
102
108

Fig. 2

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Engine Torque Control

The present invention relates to an apparatus and a method for quantifying the net torque produced by an internal combustion engine, for example, in a motor vehicle.

The net torque produced by an engine, for example an Otto or a Diesel internal combustion engine, is the total or gross torque produced by the engine, less the sum of internal and external torque losses. Internal losses are dominated by friction between the relatively moving parts of the engine. External losses may be those caused by accessories driven by the engine, such as an alternator, air conditioning unit, power steering unit, and also any torque converter losses from an automatic transmission.

It is desirable to be able to predict the net torque expected from an engine as a function of the driver demand from the accelerator pedal and gearbox setting. For example, an electronic power train control module in a motor car may control a fuel pump and fuel injectors, depending on the driver demand. An estimated net torque is useful, for example, in the control of automatic transmission and drive wheel traction control, so that gear shifts occur at the right time, and the drive wheels maintain friction with the road.

Whilst in principle, it is possible to measure and model accurately the expected net torque produced by an engine operating in a steady state condition, in practice different engines of the same type will have slightly different characteristics, and these

characteristics will vary depending on a number of factors, such as engine age and operation history. Other factors, for example, engine operating parameters which are not normally measured such as barometric pressure, relative humidity, and ambient temperature, may have an appreciable effect on the engine net torque.

A number of systems have therefore been proposed to measure or estimate the engine net torque. Most of these, however, involve a continuous adjustment of stored parameters used in torque loss calculations, at least during steady state operation of the engine. This modelling approach involves relatively complex circuitry and software in order to achieve an accurate result.

It is an object of the present invention to provide a more convenient apparatus and method for estimating the net engine torque, which does not rely on continuous or frequent adjustment of stored parameters used in torque loss calculations.

Accordingly, the invention provides an apparatus for quantifying the net torque produced by an internal combustion engine from which power may be drawn through a gearbox, comprising: means to provide a fuel delivery signal representative of an amount of fuel supplied to the engine; means to provide engine condition signals representative of a number of engine operating parameters including engine temperature and engine speed; gross torque processing means to calculate the nominal gross torque produced by the engine, the gross torque processing means receiving one or more of said signals including at least the fuel delivery signal and

calculating therefrom the nominal gross torque produced by the engine; expected loss processing means to estimate expected torque losses internal to the engine, the expected loss processing means receiving one or more of the engine condition signals and estimating therefrom the estimate of expected torque losses internal to the engine; an adaptive memory for holding expected torque loss correction values dependent on at least one of the engine operating parameters; and summation means to sum the nominal gross torque, expected torque losses and expected torque loss correction to produce an expected net torque estimate of the net torque produced by the engine; in which the apparatus comprises detection means to determine whether or not engine power is drawn through the gearbox; means to measure engine acceleration; and means to calculate an actual net torque produced by the engine from the measured engine acceleration; a torque loss correction value being generated from a difference between the expected net torque estimate, and then stored in the adaptive memory if it is determined that engine power is not drawn through the gearbox.

Also according to the invention, there is provided a method of quantifying the net torque produced by an internal combustion engine from which power may be drawn through a gearbox, comprising the steps of:

a) providing a fuel delivery signal representative of an amount of fuel supplied to the engine;
b) providing engine condition signals representative of a number of engine operating parameters including engine temperature and engine speed;
c) calculating a nominal gross torque produced by the engine using one or more of said signals including

at least the fuel delivery signal;

d) estimating expected torque losses internal to the engine using one or more of the engine condition signals;

e) storing in an adaptive memory expected torque loss correction values dependent on at least one of the engine operating parameters;

f) summing the nominal gross torque, expected torque losses and expected torque loss correction to produce an expected net torque estimate of the net torque produced by the engine;

g) determining whether or not engine power is drawn through the gearbox;

h) measuring engine acceleration;

i) calculating an actual net torque produced by the engine from the measured engine acceleration;

j) generating a torque loss correction value from a difference between the expected net torque estimate and the actual net torque; and

k) storing the torque loss correction value in the adaptive memory if it is determined that engine power is not being drawn through the gearbox.

The apparatus according to the invention may be employed as part of the motive means for a motor vehicle, comprising an internal combustion engine and a gearbox from which power may be drawn from the engine, comprising: a fuel delivery system; an engine monitoring system; and an apparatus as described herein for quantifying the net torque produced by the engine, the fuel delivery signal being provided by the fuel delivery system and the engine condition signals representative being provided by the engine monitoring system.

In a steady state condition, with no power being drawn from the engine through the gearbox, the estimated gross torque should be equal to the estimated external and internal torque losses, in which case the net torque estimate should be zero. If the actual net torque is in fact zero, then the engine will not be accelerating (which term includes decelerating). If, however, there is a discrepancy between the estimated and actual net torques, the engine will be accelerating and from the known inertia of the engine (plus any accessories driven by the engine), this acceleration can be used to calculate a correction factor, which can then be stored adaptively in, for example, a look-up table in an EEPROM or other such non-volatile memory.

The apparatus may therefore be used to correct the net torque estimate whenever the engine is not providing power through the gearbox. In the case of an automatic transmission, the torque losses in the torque converter may be considered to be losses by an accessory, and factored into the torque estimate calculation. If the gearbox is a manual transmission with a clutch, then the detection means may detect whether or not the engine is disengaged from the gears by the clutch in order to determine whether or not engine power is drawn through the gearbox.

For either a manual or an automatic transmission, it may therefore be desirable for the detection means to detect whether or not the gears are in neutral, in order to determine whether or not engine power is drawn through the gearbox.

In many cases, the engine will be driving accessories such as air conditioning units or an alternator. The

apparatus may then comprise additionally means to provide accessory condition signals representative of one or more accessory operating parameters, for example and on/off indication for an air conditioning unit, or an alternator current. The accessory loss processing means may then receive one or more of the accessory condition signals from which it may estimate expected external torque losses from the accessories driven by the engine. This estimate may then be combined with the expected torque losses internal to the engine in the summation by the summation means.

Because the correction value may fluctuate owing to sensor measurement errors or transient changing in the engine operation condition, such as a misfire, the torque loss correction value is preferably averaged over time prior to being stored in the adaptive memory.

The invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 is a block schematic diagram of an apparatus according to the invention for quantifying the net torque produced by an internal combustion engine from which power may be drawn through a gearbox; and

Figure 2 is a block schematic diagram illustrating the use of the apparatus according to the invention in a power train control module.

Figure 1 shows in block schematic form, an apparatus 1 for quantifying the net torque produced by an internal combustion engine. An estimated gross torque 2 is generated in a look-up table 4 as a function of

injected fuel quantity 6 and engine speed 8.

In this example, external torque losses are taken to be those from an air conditioning unit and alternator (not shown), both driven by the engine. The load from the air conditioning unit will be fairly constant for a given engine speed, whilst the load from the alternator will depend on the alternator current. An external torque loss estimator 10 therefore receives three signals, engine speed 8, air conditioning on or off 12, and alternator current 14, and produces an output signal for an estimated external torque loss 17.

Internal torque losses, will depend mainly on friction within the engine, which are most strongly dependent on engine speed and coolant temperature. An internal torque loss estimator 16 therefore receives inputs signals representing the engine speed 8 and the coolant temperature 18, and produces an output signal for an estimated internal torque loss 19.

Because the estimated external 17 and internal 19 torque losses will generally not be completely accurate, an adaptive loss look-up table 20 provides an output signal for a corrective torque loss 21, to be explained in more detail below. Although the inaccuracies may be due to many sources of error, these errors are generally a function of engine coolant temperature 18, and so the look-up table is arranged to provide a corrective torque loss signal depending upon an input of the coolant temperature 18.

The external, internal and corrective torque loss signals 17,19,21 are summed at nodes 22, 24, and then subtracted from the estimated gross torque at node 26

to produce an estimated net torque signal 28.

If the engine is running disconnected from the drive wheels and in a steady state, ie with no engine acceleration, then the estimated net torque should be zero. If the engine is not in a steady state, for example with the injected fuel quantity high or low for the particular engine speed, then the engine should be accelerating with either a positive or a negative estimated net torque.

Any discrepancy between the engine acceleration and the estimated net torque under these conditions in which the engine is effectively disengaged from the drive wheels, may therefore be used to calculate an actual net torque 29, which may be subtracted 30 from the estimated net torque 28 to produce a torque loss correction signal 32.

The actual net torque with the engine disengaged from the drive wheels is calculated 34 from a measured engine acceleration 36 and a known constant moment of inertia 38 for the engine (optionally adjusted for any accessories connected to the engine). In this example, the acceleration is calculated using the same engine speed signal 8 as used elsewhere in Figure 1.

If the engine is connected to an automatic transmission (as shown in phantom outline in Figure 1), then the gearbox will only occasionally be in the park setting with the engine disconnected from the drive wheels and the torque converter. It is therefore necessary, when the to factor in the torque converter losses, for the cases where the automatic transmission is in neutral, and when the transmission is in gear, but with the

vehicle stationary and no power being transmitted to the wheels. In this example, this is done in a torque converter loss estimator 40, based upon an input signal representative of transmission fluid temperature 42. An estimated torque converter torque loss signal 44 is then subtracted 46 from the previously generated torque loss correction signal 32.

The torque converter loss estimator could, of course, equivalently be placed in the section of the figure with the external and internal torque loss, as an automatic transmission results in another form of external torque loss, but in this implementation, the torque converter loss estimator 40 is separate so that the circuitry in the case of a manual transmission is kept simple.

The torque loss correction signal is then averaged 50 to reduce noise and transient signals, and then a torque loss correction value 51 is factored back into the adaptive loss look-up table if no engine power is being supplied to the wheels 52.

Figure 2 shows how the apparatus 1 described above may be used in a power train control module 101 and with a diesel engine 102 in a vehicle having a traction control module 104 and an automatic transmission control module 106.

The engine comprises known means 108 to measure engine speed, which although not illustrated are in the form of a toothed wheel and sensor arrangement on the engine crankshaft. These provide a plurality of pulses 110 for each revolution of the engine 102, to the acceleration determination module 36. The engine

acceleration measurement is then used in the manner described above to produce the corrected net torque estimate, which is used in the calculations of fuel-to torque 114 and torque-to-fuel 112 for the fuel control system 116, as well as in the traction control 104 and automatic transmission control 106 modules in which the gearbox includes a sensor to detect if the gear box is in neutral in order to determine whether or not engine power is drawn through the gearbox.

Also part of the automatic transmission control module 106 is a gearbox sensor 120 which detects if the gears are disengaged from the engine in order to determine whether or not engine power is drawn through the gearbox.

The invention may therefore be used to obtain an accurate and convenient control over the fuel control system, according to the demands placed upon the engine by the driver, and the limitation or constraints required by the other controls such as traction control and automatic gearbox operation.

Claims

1. An apparatus for quantifying the net torque produced by an internal combustion engine from which power may be drawn through a gearbox, comprising: means to provide a fuel delivery signal representative of an amount of fuel supplied to the engine; means to provide engine condition signals representative of a number of engine operating parameters including engine temperature and engine speed; gross torque processing means to calculate the nominal gross torque produced by the engine, the gross torque processing means receiving one or more of said signals including at least the fuel delivery signal and calculating therefrom the nominal gross torque produced by the engine; expected loss processing means to estimate expected torque losses internal to the engine, the expected loss processing means receiving one or more of the engine condition signals and estimating therefrom the estimate of expected torque losses internal to the engine; an adaptive memory for holding expected torque loss correction values dependent on at least one of the engine operating parameters; and summation means to sum the nominal gross torque, expected torque losses and expected torque loss correction to produce an expected net torque estimate of the net torque produced by the engine; in which the apparatus comprises detection means to determine whether or not engine power is drawn through the gearbox; means to measure engine acceleration; and means to calculate an actual net torque produced by the engine from the measured engine acceleration; a torque loss correction value being generated from a difference between the expected net torque estimate, and then stored in the adaptive memory if it is determined that engine power is not drawn

through the gearbox.

2. An apparatus as claimed in Claim 1, in which the detection means detects whether or not the gears are in neutral in order to determine whether or not engine power is drawn through the gearbox.

3. An apparatus as claimed in Claim 1 or Claim 2, in which the apparatus comprises additionally means to provide accessory condition signals representative of one or more accessory operating parameters; and accessory loss processing means to estimate expected torque losses from accessories driven by the engine, the accessory loss processing means receiving one or more of the accessory condition signals and estimating therefrom the estimate of expected torque losses external to the engine, said estimate being combined with the expected torque losses internal to the engine in the summation by the summation means.

4. An apparatus as claimed in Claim 3, in which an accessory is an automatic gearbox with a torque converter which contributes to the external torque losses.

5. An apparatus as claimed in any one of Claims 1 to 3, in which the gearbox is a manual transmission with a clutch, and the detection means detects whether or not the engine is disengaged from the gears by the clutch in order to determine whether or not engine power is drawn through the gearbox.

6. An apparatus as claimed in any preceding claim, in which the torque loss correction value is averaged over time prior to being stored in the adaptive memory.

7. A motive means for a motor vehicle, comprising an internal combustion engine and a gearbox from which power may be drawn from the engine, comprising: a fuel delivery system; an engine monitoring system; and an apparatus as claimed in any one of Claims 1 to 6 for quantifying the net torque produced by the engine, the fuel delivery signal being provided by the fuel delivery system and the engine condition signals representative being provided by the engine monitoring system.

8. A motive means as claimed in Claim 7, in which the means to measure engine speed includes a toothed wheel and sensor arrangement on the engine crankshaft which provides a plurality of pulses for each revolution of the engine, the means to measure engine acceleration using these pulses as a measure of engine acceleration.

9. A motive means as claimed in Claim 7 or Claim 8, in which the gearbox includes a sensor to detect if the gear box is in neutral in order to determine whether or not engine power is drawn through the gearbox.

10. A motive means as claimed in any one of Claims 7 to 9, in which the gearbox includes a sensor to detect if the gears are disengaged from the engine in order to determine whether or not engine power is drawn through the gearbox.

11. A method of quantifying the net torque produced by an internal combustion engine from which power may be drawn through a gearbox, comprising the steps of:

a) providing a fuel delivery signal

representative of an amount of fuel supplied to the engine;

b) providing engine condition signals representative of a number of engine operating parameters including engine temperature and engine speed;

c) calculating a nominal gross torque produced by the engine using one or more of said signals including at least the fuel delivery signal;

d) estimating expected torque losses internal to the engine using one or more of the engine condition signals;

e) storing in an adaptive memory expected torque loss correction values dependent on at least one of the engine operating parameters;

f) summing the nominal gross torque, expected torque losses and expected torque loss correction to produce an expected net torque estimate of the net torque produced by the engine;

g) determining whether or not engine power is drawn through the gearbox;

h) measuring engine acceleration;

i) calculating an actual net torque produced by the engine from the measured engine acceleration;

j) generating a torque loss correction value from a difference between the expected net torque estimate and the actual net torque; and

k) storing the torque loss correction value in the adaptive memory if it is determined that engine power is not being drawn through the gearbox.

12. An apparatus for quantifying the net torque produced by an internal combustion engine from which power may be drawn through a gearbox, substantially as

herein described, with reference to the accompanying drawings.

13. A motive means for a motor vehicle, substantially as herein described, with reference to the accompanying drawings.

14. A method of quantifying the net torque produced by an internal combustion engine from which power may be drawn through a gearbox, substantially as herein described, with reference to the accompanying drawings.

The Patent Office

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Application No: GB 9720742.7
Claims searched: 1-11

Examiner: Andrew Bartlett
Date of search: 18 February 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G1N (AAJCR, AAJE); G3N (NGBXB, NGBXX)

Int Cl (Ed.6): G01L 3/00; G01M 15/00; F02D 41/08 & 41/16

Other: Online:- WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	US 5484351 (ZHANG et al) See col 7 line 60 - col 8 line 65 in particular	1-5 & 7-11

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.