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(71) Applicant: CUMMINS, INC. [US/US]; 500 Jackson Street, Columbus, Indiana 47201 (US).

(72) Inventors; and

(71) Applicants (for US only): WANG, Pan [CN/CN]; 6 Checheng N. Road, Wuhan E&T Development Zone, Wuhan, Hubei 430056 (CN). ZHANG, Roger S. [CN/CN]; 6 Checheng N. Road, Wuhan E&T Development Zone, Wuhan, Hubei 430056 (CN). WANG, Joey [CN/CN]; Gateway Plaza, Tower A, 28/F, 18 Xiaguangli East Third Ring Rd. North, Beijing 100027 (CN). SHU, Keyi [CN/CN]; 6 Checheng N. Road, Wuhan E&T Development Zone, Wuhan, Hubei 430056 (CN).

(74) Agent: XU & PARTNERS, LLC.; Room No.106, Building No.1, Universal High-Tech Plaza, 958 Zhen Bei Road, Putuo District, Shanghai 200333 (CN).

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(54) Title: SYSTEM AND METHOD FOR LOAD-BASED ACCELERATION CONTROL

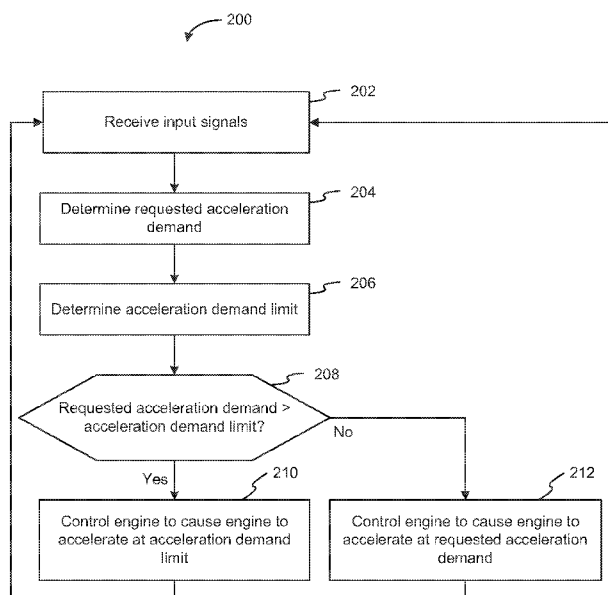


Fig. 2

(57) Abstract: A method of controlling acceleration of an internal combustion engine (108) is disclosed. The method includes receiving an engine speed input (304) and a load parameter input (306). The method also includes determining a requested acceleration demand and determining an acceleration demand limit (310) based on the engine speed input (304) and the load parameter input (306). In addition, the method includes limiting the requested acceleration demand to the acceleration demand limit (310) if the requested acceleration demand exceeds the acceleration demand limit (310).

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KM, ML, MR, NE, SN, TD, TG).

— *with international search report (Art. 21(3))*

SYSTEM AND METHOD FOR LOAD-BASED ACCELERATION CONTROL

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to the field of control systems for internal combustion engines, and more particularly to control systems for internal combustion engines including load-based acceleration control.

[0002] Internal combustion (IC) engines generate power necessary to propel a vehicle and/or to power auxiliary loads. An IC engine's power output is a function of its torque multiplied by its engine speed. Torque performance is typically illustrated by a torque curve, which is a plot of an engine's maximum load (e.g., torque) capacity across a range of engine speeds. For every engine speed, there is a maximum torque capacity. In general, IC engine performance, fuel efficiency, and emissions are optimized when engine torque requirements are matched to specific engine speeds. Thus, as torque demands change, it is desirable to control engine speed to the most efficient speeds for particular torque demands.

SUMMARY OF THE INVENTION

[0003] One embodiment relates to a method of controlling acceleration of an internal combustion engine. The method includes receiving an engine speed input and a load parameter input. The method also includes determining a requested acceleration demand and determining an acceleration demand limit based on the engine speed and the load parameter. In addition, the method includes limiting the requested acceleration demand to the acceleration demand limit if the requested acceleration demand exceeds the acceleration demand limit.

[0004] Another embodiment relates to an acceleration demand management system. The system includes a vehicle including an internal combustion engine and a transmission, and a processor coupled to the internal combustion engine and to the transmission. The processor is configured to receive an engine speed input and a load parameter input. The processor is also configured to determine a requested acceleration demand and to determine an acceleration demand limit based on the engine speed input and the load

parameter input. In addition, the processor is configured to limit the requested acceleration demand to the acceleration demand limit if the requested acceleration demand exceeds the acceleration demand limit.

[0005] Still another embodiment relates to a tangible, non-transitory computer-readable storage medium having machine instructions stored therein, the instructions being executable by a processor to cause the processor to receive an engine speed input and a load parameter input. The instructions also cause the processor to determine a requested acceleration demand and to determine an acceleration demand limit based on the engine speed input and the load parameter input. In addition, the instructions also cause the processor to limit the requested acceleration demand to the acceleration demand limit if the requested acceleration demand exceeds the acceleration demand limit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a block diagram of a vehicle capable of load-based acceleration control according to an example embodiment of the present disclosure.

[0007] FIG. 2 is a flow diagram of a method of load-based acceleration control according to example embodiments of the present disclosure.

[0008] FIG. 3 is a block diagram of a load-based acceleration control module configured to determine an acceleration demand limit according to an example embodiment of the present disclosure.

[0009] FIG. 4 is a block diagram of a load-based acceleration control module according to an example embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] During vehicle operation, an internal combustion (IC) engine generates torque to propel the vehicle and/or to power auxiliary loads. For example, to accelerate a vehicle, an operator adjusts an accelerator pedal or throttle lever to directly demand a particular torque from the engine. At the same time, other vehicle systems may independently demand additional torque from the engine. For example, heavy-duty equipment such as trucks, tractors, construction equipment and the like may include auxiliary loads such as power take-offs (PTOs) and pumps that demand additional torque from the engine. In addition,

other engine-powered devices (e.g., air-conditioner compressors, alternators, servo pumps, etc.) may also demand torque from the engine.

[0011] Torque demand during vehicle operation can be highly variable based on variable loads applied to the engine. For example, a loader performing a digging operation experiences significant variations in load and, therefore, the loader's engine experiences significantly variable torque demand. During a digging operation, torque demand increases sharply as the loader positions a tool (e.g., a bucket) to engage a load (e.g., earth), and decreases sharply when the loader dumps the load.

[0012] In existing vehicles, operators may respond to changes in torque demand by manually changing the accelerator position (e.g., throttling) and/or by shifting to different transmission gears. In other situations, such as a loader performing a digging operation, an operator may set the throttle to a position at which the engine can produce the maximum torque that is demanded during the digging operation. Both examples result in inefficient engine operation and increased fuel consumption because operators may overestimate or underestimate required torque and/or may respond poorly, if at all, to changes in torque demand. As mentioned above, IC engines typically operate most efficiently at a particular engine speed for a given torque demand. To that end, the present disclosure provides a control system that controls engine speed based on torque demand and, therefore, based on load, such that the engine operates at optimal engine speeds for variable loads.

[0013] An engine must accelerate or decelerate engine speed to reach a desired engine speed that is different from its current speed. Engine acceleration refers to a rate of change of engine speed, which is typically expressed in terms of revolutions per minute per second (i.e., RPM/s). Colloquially, engine acceleration is commonly referred to as “ $\dot{n}$.” The variable n is commonly used to represent engine speed, therefore “ $\dot{n}$ ” represents the time derivative of engine speed, i.e., engine acceleration.

[0014] Engine acceleration has been found to have a significant influence on an engine's fuel efficiency and exhaust emissions performance. In particular, high engine acceleration rates, such as those experienced during free acceleration (e.g., wide-open throttle) contribute significantly to overall fuel consumption and to the formation of diesel particulate matter (e.g., soot or “black smoke”). To that end, the present disclosure provides systems and methods for controlling an IC engine based on engine acceleration.

In addition, in accordance with load-based control mentioned above, the present disclosure provides systems and methods of load-based acceleration control of an IC engine.

[0015] In an example embodiment, improved fuel efficiency may be realized when engine acceleration is limited (e.g., to 200 RPM/s) without any appreciable changes to operational efficiency. In another example embodiment, load-based acceleration control reduced exhaust emissions to the extent that load-based acceleration control may be utilized instead of oxygen/fuel control (OFC) to control free acceleration smoke for engine platforms that do not include a temperature manifold absolute pressure (TMAP) sensor. Thus, reduced component costs can be realized by implementing load-based acceleration control.

[0016] Engine acceleration control, however, involves a trade-off between engine responsiveness (e.g., transient response) versus fuel efficiency and emissions. In general, stricter engine acceleration limits result in improved fuel efficiency and emissions, but result in diminished responsiveness. However, operators place different priorities on fuel efficiency, emissions, and responsiveness depending on particular applications and/or operating conditions. For example, an operator driving a long distance on a highway may select an “economy” mode to place a high priority on fuel efficiency and emissions and a low priority on responsiveness. In contrast, a heavy-equipment operator may select a “power” mode to place a high priority on responsiveness and a low priority on fuel efficiency and emissions. To that end, the present disclosure provides systems and methods for load-based acceleration control of an IC engine including optimizations based on priorities associated with particular applications.

[0017] External factors such as altitude and temperature can also affect fuel efficiency and exhaust emissions. Atmospheric pressure drops as altitude increases such that cylinders of an engine are charged with less air compared to an engine operating under the same conditions at a lower altitude. Accordingly, the injected fuel quantity must be reduced to avoid excessive particulate matter (e.g., soot) emissions. In addition, combustion temperature has a significant influence on the formation of NO_x and other pollutants. To that end, the present disclosure provides systems and methods for load-based acceleration control of an IC engine including optimizations based on external factors such as altitude and temperature.

[0018] Turning to FIG. 1, a block diagram of a vehicle 100 capable of load-based acceleration control is illustrated according to an example embodiment of the present disclosure. In general, the vehicle 100 includes a powertrain 102, numerous vehicle sensors 104, and an electronic control system 106. The powertrain 102 includes an IC engine 108 operatively coupled to a transmission 110. The IC engine 108 can be powered by any of several different types of fuel, such as gasoline, diesel, or natural gas, among others. The transmission 110 includes a plurality of gears through which torque is transferred from the IC engine 108 to satisfy various torque demands 112. In other embodiments, the transmission 110 is a continuously variable transmission. Such torque demands 112 can include propulsion torque demands 114, auxiliary load torque demands 116, and/or other torque demands 118.

[0019] The electronic control system 106 is operatively coupled to the powertrain 102 and to the vehicle sensors 104 via a bus, such as a Communications Area Network (CAN) bus 120. The electronic control system 106 receives signals (e.g., vehicle parameter inputs) from the vehicle sensors 104, which can include hundreds of sensors that measure a wide range of vehicle operating parameters and operator inputs 122 (e.g., accelerator position, operating mode selection, etc.). The electronic control system 106 analyzes the signals received from the vehicle sensors 104 and outputs control signals to control various aspects of the powertrain 102 and other vehicle components.

[0020] The electronic control system 106 includes various control modules such as an Engine Control Module (ECM) 124, a Transmission Control Module (TCM) 126, and/or other control modules 128, such as a body control module, a telematics control module, and the like. In addition, the electronic control system 106 also includes a load-based acceleration control (LBAC) module 130. In the example embodiment depicted in FIG. 1, the LBAC module 130 is incorporated into the ECM 124; however, in other example embodiments, the LBAC module 130 is a stand-alone module or is incorporated in other control modules, such as the TCM 126. Moreover, in other example embodiments, certain control modules are integrated into a single module. For example, in certain example embodiments, the ECM 124 and TCM 126 are integrated into a Powertrain Control Module (PCM). In addition to receiving signals from vehicle sensors 104, the ECM 124, the TCM 126, the other control modules 128, and the LBAC module 130 are in operative communication with each other via the CAN bus 120.

[0021] As mentioned above, the electronic control system 106, including the ECM 124, the TCM 126, and the LBAC module 130 provide systems and methods for load-based acceleration control of the IC engine 108. In certain embodiments, the load-based acceleration control includes further optimizations based on external factors (e.g., altitude and/or temperature) and/or based on priorities associated with particular applications.

[0022] Turning now to FIG. 2, a flow diagram of a method 200 of load-based acceleration control is shown according to example embodiments of the present disclosure. The method 200 can be performed, for example, by the electronic control system 106 or, more specifically, by the LBAC module 130 of FIG. 1. For clarity and brevity, the method 200 will be explained with respect to the LBAC module 130 of FIG. 1. However, the method can be performed by the electronic control system 106 in general or, more specifically by the ECM 124, the TCM 126, the other control modules 128, the LBAC module 130, or any combination thereof.

[0023] At block 202, the LBAC module 130 receives input signals (e.g., vehicle parameter inputs). The input signals can be received over the CAN bus 120 or directly from other devices. The input signals can include the torque demands 112 and speed of the IC engine 108, other inputs from the vehicle sensors 104 (e.g., compressor inlet density, coolant temperature, etc.), and/or operator inputs 122 (e.g., accelerator position, operating mode, etc.), among others.

[0024] At block 204, the LBAC module 130 determines a requested acceleration demand. To do so, the LBAC module 130 determines a total torque (i.e., load) demand 112 on the IC engine 108, and determines an optimal engine speed to produce that torque demand 112. The LBAC module 130 then compares the current engine speed to the optimal engine speed and calculates a requested acceleration demand to cause the engine to reach the optimal engine speed.

[0025] At block 206, the LBAC module 130 determines an acceleration demand limit. To do so, the LBAC module 130 analyzes the current engine speed and a load parameter based on the current total torque (i.e., load) demand 112. In an example embodiment, the load parameter is a percentage of the maximum load capacity of the engine at the current engine speed (i.e., percent load at current speed). However, in other example embodiments, the load parameter may simply be load or any parameter relating to load. The LBAC

module 130 then determines an acceleration demand limit based on the current engine speed and the load parameter. In an example embodiment, the LBAC module 130 accesses look-up tables that specify optimal acceleration demand limits based on particular engine speeds and load parameters. In certain example embodiments, the LBAC module 130 includes a plurality of look-up tables, each corresponding to priorities associated with particular operating modes. For example, an “economy” mode may have stricter acceleration demand limits than a “power” mode. In certain example embodiments, the operating mode is selected by an operator (e.g., via the operator inputs 122 of FIG. 1). However, in other example embodiments, the electronic control system 106 (via, e.g., the ECM 124) automatically determines the operating mode based on vehicle operating parameters (via, e.g., the vehicle sensors 104).

[0026] In certain example embodiments, the LBAC module 130 adjusts the acceleration demand limit based on external factors such as altitude and temperature. For example, an altitude adjustment may be made based on a compressor inlet density measurement value. In another example, temperature adjustments may be made based on an engine coolant temperature measurement value. In these examples, the LBAC module 130 compares such measurement values to respective look-up tables to determine a gain multiplier that is then applied to the acceleration demand limit to adjust its value based on those external factors.

[0027] At block 208, the LBAC module 130 determines if the requested acceleration demand of block 204 exceeds the acceleration demand limit of block 206. If the result of block 208 is “yes,” at block 210, the LBAC module 130 outputs a control signal (via, e.g., the ECM 124 of FIG. 1) to cause the IC engine 108 to accelerate at the acceleration demand limit of block 206. If the result of block 208 is “no,” at block 212, the LBAC module 130 outputs a control signal (via, e.g., the ECM 124 of FIG. 1) to cause the IC engine 108 to accelerate at the requested acceleration demand of block 204. The method 200 of load-based acceleration control repeats at block 202 at the next instant.

[0028] Turning to FIG. 3, a block diagram of an example LBAC module 300 (e.g., the LBAC module 130 of FIG. 1) configured to determine an acceleration demand limit (e.g., as in block 206 of FIG. 2) according to an example embodiment. The LBAC module 300 includes LBAC enable conditions 302, which indicate whether or not to enable LBAC. In certain example embodiments, the LBAC enable conditions 302 are determined based on an operator input (e.g., the operator inputs 122 of FIG. 1). In other example embodiments,

the LBAC enable conditions 302 are determined automatically based on vehicle operating parameters (via, e.g., the vehicle sensors 104 of FIG. 1).

[0029] If the LBAC enable conditions 302 indicate that LBAC is enabled, the LBAC module 300 analyzes the current engine speed 304 and a load parameter 306 (e.g., percent load at current speed) according to look-up tables 308 to determine a base engine acceleration limit 310. The LBAC module 300 determines which of a plurality of look-up tables 300 to analyze based on an operating mode 312. An example embodiment includes a “standard” mode, an “economy” mode, and a “power” mode. The look-up tables 308 for each of the operating modes 312 are specific to each respective operating mode 312 based on responsiveness priorities associated with each respective operating mode 312. In certain example embodiments, the operating mode 312 is selected by an operator (e.g., via the operator inputs 122 of FIG. 1). However, in other example embodiments, the electronic control system 106 (e.g., via the ECM 124) automatically determines the operating mode 312 based on vehicle operating parameters (e.g., via the vehicle sensors 104).

[0030] In certain example embodiments, the LBAC module 300 adjusts the acceleration demand limit based on external factors. For example, an altitude adjustment 314 gain multiplier and/or a temperature adjustment 316 gain multiplier can be applied to the base engine acceleration limit 310 to determine an adjusted acceleration demand limit 318. The LBAC module 300 outputs the base acceleration demand limit 310 or the adjusted acceleration demand limit 318 to an ECM (e.g., the ECM 124 of FIG. 1), which limits engine acceleration to the base acceleration demand limit 310 or the adjusted accelerated demand limit 318.

[0031] Turning now to FIG. 4, a block diagram of an LBAC module 400 according to an example embodiment is illustrated. The LBAC module 400 receives vehicle operating parameters 402, which can include signals from vehicle sensors (e.g., the vehicle sensors 104 of FIG. 1) and/or from other components of the electronic control system (e.g., the electronic control system 106 of FIG. 1). In an example embodiment, the vehicle operating parameters 402 include engine speed 404, a load parameter 406, coolant temperature 408, and/or compressor inlet density 410.

[0032] A lead/lag compensator 412 receives the engine speed 404 and the load parameter 406. The lead/lag compensator 412 is implemented to account for potential driveline oscillation and to improve the transient response, stability, and steady-state error of the LBAC module 400.

[0033] The LBAC module 400 includes an engine speed and load adjust sub-module 414. The engine speed and load adjust sub-module receives as inputs the engine speed 404 and the load parameter 406 from the lead/lag compensator 412, and analyzes those values with respect to an Ndot table 416 to determine a baseline engine acceleration demand (e.g., Ndot) limit 418.

[0034] In certain embodiments, the LBAC module 400 also includes a coolant temperature adjust sub-module 420 and/or an altitude adjust sub-module 422. The coolant temperature adjust sub-module 420 analyzes the coolant temperature 408 with respect to a temperature gain table 424 to determine a temperature gain multiplier 426. The altitude adjust sub-module 422 analyzes the compressor inlet density 410 with respect to an altitude gain table 428 to determine an altitude gain multiplier 430. The temperature gain multiplier 426 and the altitude gain multiplier 430 are applied to the baseline engine acceleration demand limit 408 at the junction 432 to produce an adjusted engine acceleration demand limit 434.

[0035] The LBAC module 400 outputs the baseline engine acceleration demand limit 418 or the adjusted engine acceleration demand limit 434 to an ECM (e.g., the ECM 124 of FIG. 1), which limits engine acceleration to the base acceleration demand limit 418 or the adjusted accelerated demand limit 434.

[0036] It should be noted that the term “example” as used herein to describe various embodiments is intended to indicate that such embodiments are possible examples, representations, and/or illustrations of possible embodiments (and such term is not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0037] The present disclosure contemplates methods, systems, and program products on any machine-readable media for accomplishing various operations. As mentioned above, in certain embodiments, the LBAC module forms a processing system or subsystem that

includes one or more computing devices having memory, processing, and communication hardware. The LBAC module may be a single device or a distributed device, and the functions of the processor may be performed by hardware and/or as computer instructions on a non-transient computer (or machine) readable storage medium. Such computer-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such computer-readable media can comprise RAM, ROM, EPROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. In certain embodiments, the LBAC module includes one or more modules structured to functionally execute the operations described herein. The description herein including the components of the LBAC module emphasizes the structural independence of the aspects of the LBAC module, and illustrates one grouping of operations and responsibilities of the LBAC module. Other groupings that execute similar overall operations are understood within the scope of the present application. Modules may be implemented in hardware and/or as computer instructions on a non-transient computer readable storage medium, and modules may be distributed across various hardware or computer based components.

[0038] Example and non-limiting module implementation elements include sensor (e.g., sensors 110) providing any value determined herein, sensors providing any value that is a precursor to a value determined herein, datalink and/or network hardware including communication chips, oscillating crystals, communication links, cables, twisted pair wiring, coaxial wiring, shielded wiring, transmitters, receivers, and/or transceivers, logic circuits, hard-wired logic circuits, reconfigurable logic circuits in a particular non-transient state configured according to the module specification, any actuator including at least an electrical, hydraulic, or pneumatic actuator, a solenoid, an op-amp, analog control elements (springs, filters, integrators, adders, dividers, gain elements), and/or digital control elements.

[0039] While various embodiments of the disclosure have been shown and described, it is understood that these embodiments are not limited thereto. The embodiments may be changed, modified and further applied by those skilled in the art. Therefore, these

embodiments are not limited to the detail shown and described previously, but also include all such changes and modifications.

WHAT IS CLAIMED IS:

1. A method of controlling acceleration of an internal combustion engine, comprising:
 - receiving an engine speed input and a load parameter input;
 - determining a requested acceleration demand;
 - determining an acceleration demand limit based on the engine speed input and the load parameter input; and
 - limiting the requested acceleration demand to the acceleration demand limit if the requested acceleration demand exceeds the acceleration demand limit.
2. The method of claim 1, further comprising receiving a compressor inlet density input, wherein determining the acceleration demand limit is further based on the compressor inlet density input.
3. The method of claim 1, further comprising receiving a coolant temperature input, wherein determining the acceleration demand limit is further based on the coolant temperature input.
4. The method of claim 1, further comprising determining an operating mode, and wherein determining the acceleration demand limit is further based on the operating mode.
5. The method of claim 4, wherein the operating mode is selected by an operator via an operator input.
6. The method of claim 4, further comprising receiving vehicle parameter inputs and determining the operating mode based on the vehicle parameter inputs.

7. An acceleration demand management system for a vehicle including an internal combustion engine and a transmission, the system comprising:

a processor coupled to the internal combustion engine and to the transmission, the processor configured to:

receive an engine speed input and a load parameter input;

determine a requested acceleration demand;

determine an acceleration demand limit based on the engine speed input and the load parameter input; and

limit the requested acceleration demand to the acceleration demand limit if the requested acceleration demand exceeds the acceleration demand limit.

8. The system of claim 7, wherein the processor is further configured to receive a compressor inlet density input, and wherein the processor is configured to determine the acceleration demand limit further based on the compressor inlet density input.

9. The system of claim 7, wherein the processor is further configured to receive a coolant temperature input, and wherein the processor is configured to determine the acceleration demand limit further based on the coolant temperature input.

10. The system of claim 7, wherein the processor is further configured to receive an operating mode input, and wherein the processor is configured to determine the acceleration demand limit further based on the operating mode input.

11. The system of claim 10, wherein the operating mode is selected by an operator via an operator input.

12. The system of claim 10, wherein the processor is further configured to receive vehicle parameter inputs and to determine the operating mode based on the vehicle parameter inputs.

13. A tangible, non-transitory computer-readable storage medium having machine instructions stored therein, the instructions being executable by a processor to cause the processor to perform operations, comprising:

receiving an engine speed input and a load parameter input;

determining a requested acceleration demand;
determining an acceleration demand limit based on the engine speed input and the load parameter input; and
limiting the requested acceleration demand to the acceleration demand limit if the requested acceleration demand exceeds the acceleration demand limit.

14. The tangible, non-transitory computer-readable storage medium of claim 13, the operations further comprising receiving a compressor inlet density input, and wherein calculating the acceleration demand limit is further based on the compressor inlet density input.

15. The tangible, non-transitory computer-readable storage medium of claim 13, the operations further comprising receiving a coolant temperature input, and wherein calculating the acceleration demand limit is further based on the coolant temperature input.

16. The tangible, non-transitory computer-readable storage medium of claim 13, the operations further comprising determining an operating mode, and wherein calculating the acceleration demand limit is further based on the operating mode.

17. The tangible, non-transitory computer-readable storage medium of claim 16, wherein the operating mode is selectable by an operator via an operator input.

18. The tangible, non-transitory computer-readable storage medium of claim 16, the operations further comprising receiving vehicle parameter inputs and determining the operating mode based on the vehicle parameter inputs.

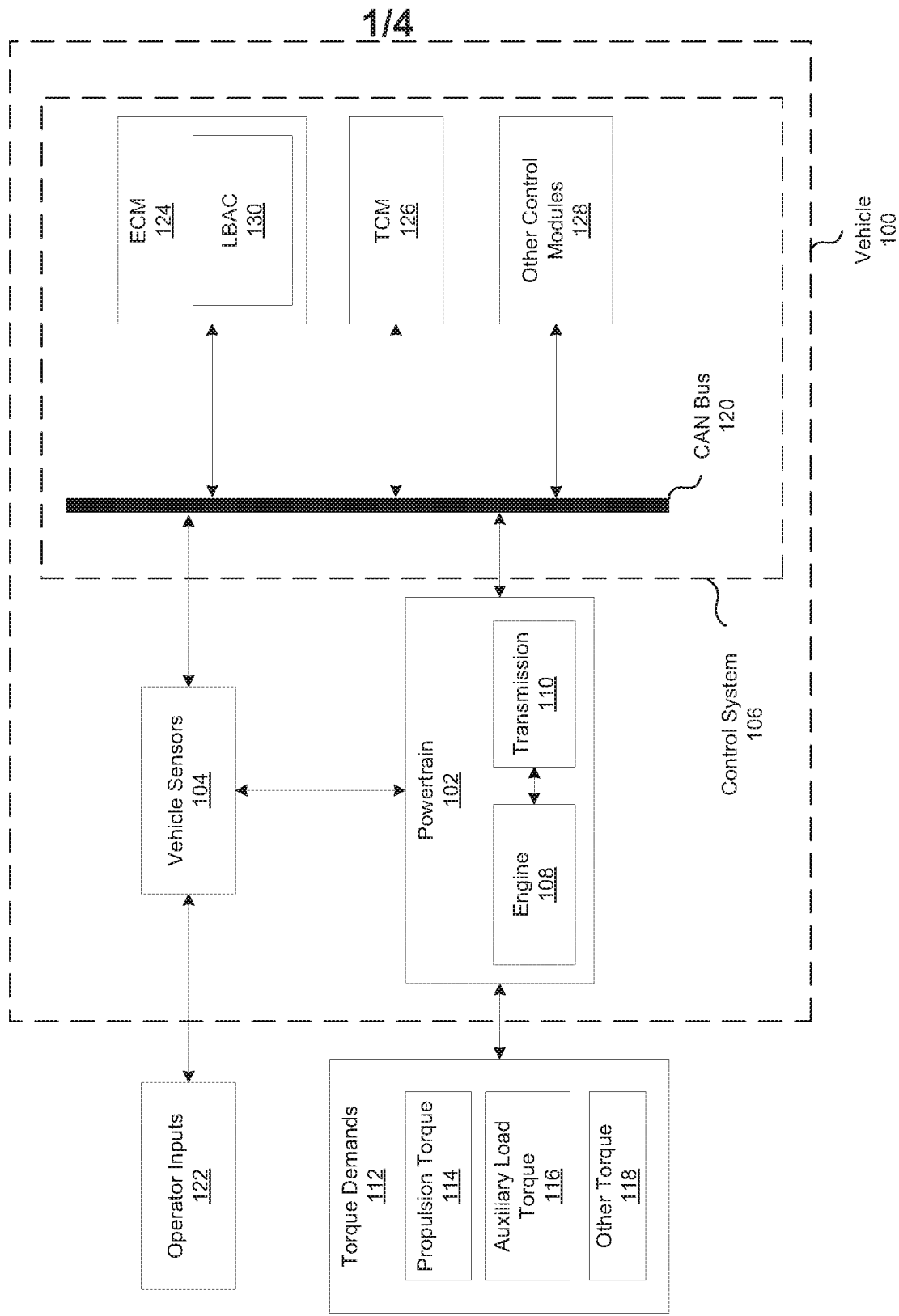


Fig. 1

2/4

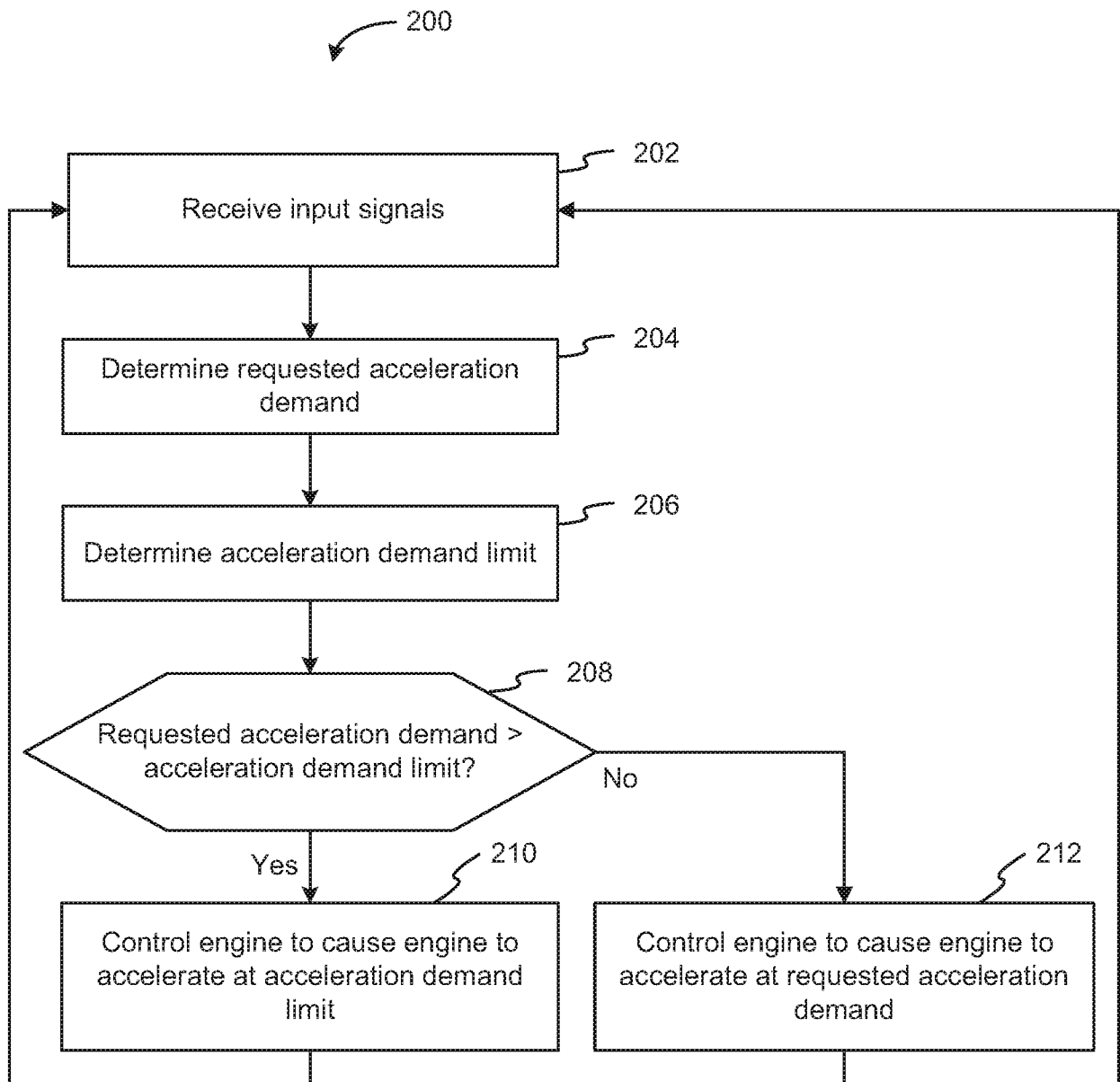


Fig. 2

3/4

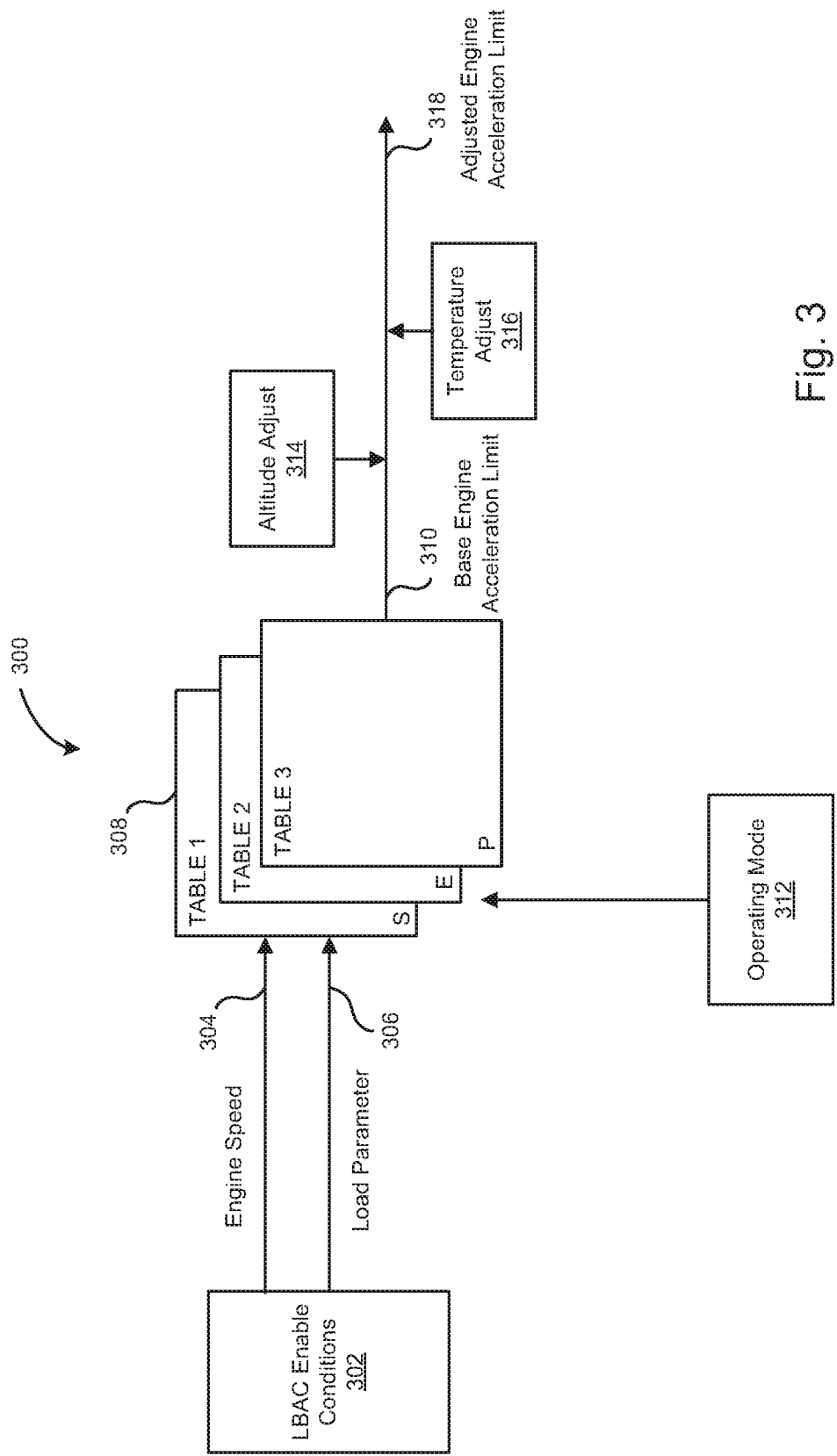


Fig. 3

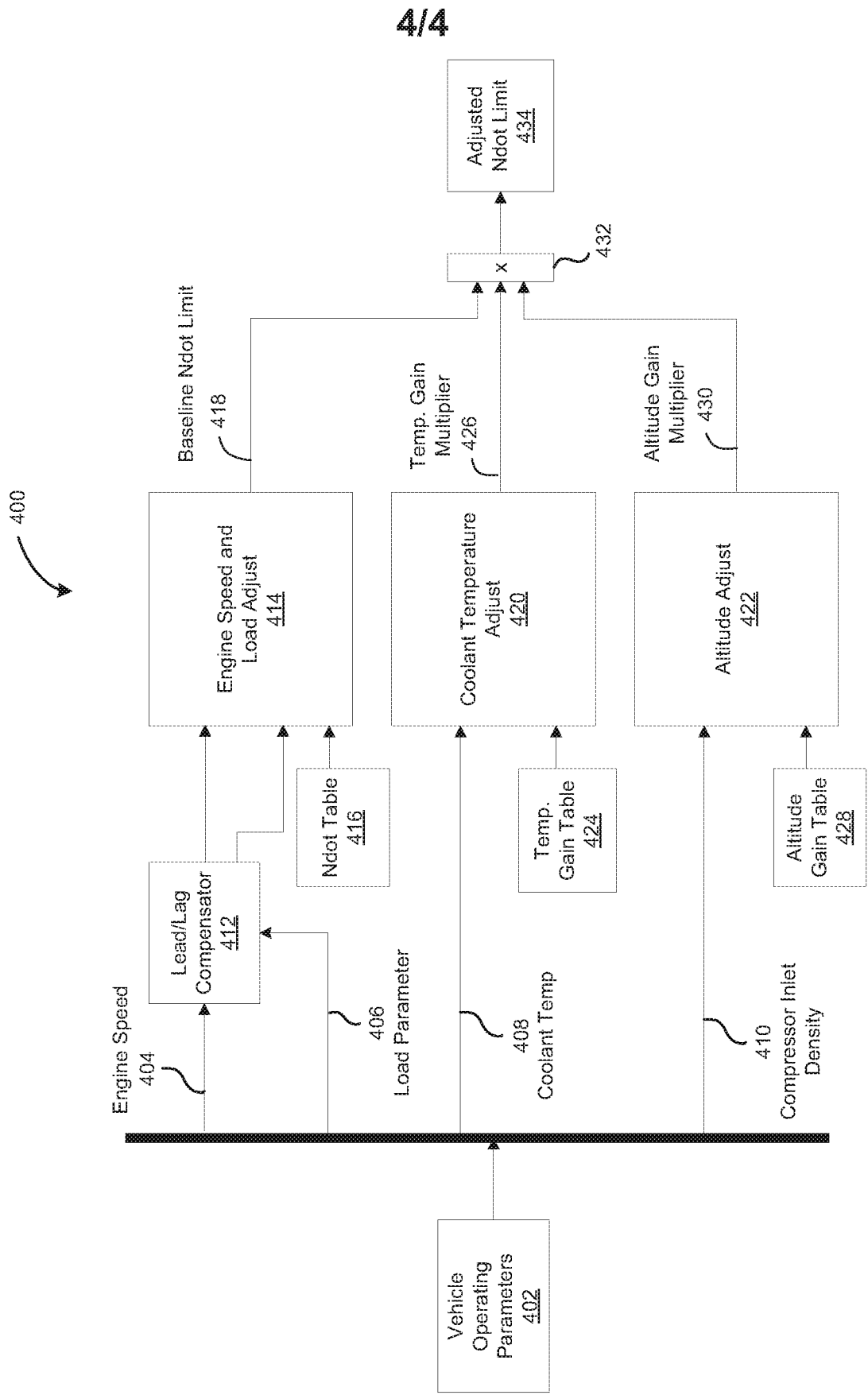


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2014/074411

A. CLASSIFICATION OF SUBJECT MATTER

F02D 29/02(2006.01)i

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)

F02D; B60W

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

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

CNPAT, CNKI, WPI, EPODOC: 发动机, 控制, 加速度, 速度, 输入, 负荷, 载荷, 限值, 限制, 阈值, engine, control, acceleration, speed, input, load, limit

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102235252 A (GM GLOBAL TECHNOLOGY OPERATIONS INC) 09 November 2011 (2011-11-09) description, paragraphs 0041-0141 and figures 1-6	1-18
X	DE 102011120570 A1 (GM GLOBAL TECHNOLOGY OPERATIONS INC) 14 June 2012 (2012-06-14) description, paragraphs 0052-0138 and figures 1-6	1-18
X	US 2013096808 A1 (FORD GLOBAL TECHNOLOGIES LLC) 18 April 2013 (2013-04-18) description, paragraphs 0023-0069 and figures 1-8	1-18
A	EP 2568148 A1 (KOMATSU LTD) 13 March 2013 (2013-03-13) the whole document	1-18
A	JP 2012011935 A (ADVICS CO LTD) 19 January 2012 (2012-01-19) the whole document	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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“&” document member of the same patent family

Date of the actual completion of the international search

17 December 2014

Date of mailing of the international search report

26 December 2014

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

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