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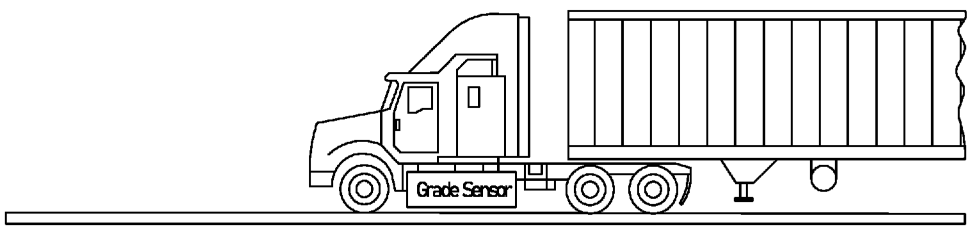

FIG. 1

(57) Abstract: Disclosed herein are systems and methods, implementable in a vehicle equipped with adaptive cruise control, for maintaining in a subject vehicle substantially constant following distance relative to a preceding target vehicle where there has been a change in slope of a surface on which the subject vehicle is travelling and/or where pitch of the subject vehicle has changed. Systems and methods disclosed herein may maintain such substantially constant following distance by managing degree of engine braking. Such engine braking management effective for maintaining substantially constant following distance relative to a preceding target vehicle, notwithstanding change in driving surface slope and/or change in pitch of the subject vehicle, may be realized based on data received into the subject vehicle's electronic control unit through sensors for detecting surface slope and sensors for detecting vehicle pitch, which may be located on the subject vehicle.

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SYSTEMS AND METHODS FOR MANAGING VEHICLE FOLLOWING DISTANCE USING ENGINE BRAKING

REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims benefit of United States Patent Application Number 17/880,389, filed on August 3, 2022. That patent application is incorporated herein in its entirety by this reference.

FIELD OF THE INVENTION

[0002] The present invention relates to systems and methods for managing the distance between a subject vehicle, with an adaptive cruise control feature activated, and a target vehicle preceding the subject vehicle. The present invention relates to systems and methods for managing vehicle following distance by managing degree of engine braking in the subject vehicle.

BACKGROUND

[0003] Conventional cruise control may be used to maintain a substantially constant vehicle speed that has been pre-set. Early forms of conventional cruise control maintained the substantially constant vehicle speed by adjusting throttle valve position using a cable. As technology progressed, cruise control systems began to operate electronically. In a vehicle containing a gasoline engine, the vehicle's electronic control unit (ECU) will send a command signal to modify throttle valve opening as necessary to maintain substantially constantly the pre-set vehicle speed. In a vehicle containing a diesel engine, the vehicle's ECU will send a command signal to adjust the amount of fuel being injected into the engine cylinders as necessary to maintain substantially constantly the pre-set vehicle speed.

[0004] Conventional adaptive cruise control (ACC) likewise may be used to maintain a substantially constant vehicle speed. Conventional ACC additionally includes the ability to maintain a substantially constant following distance in a subject vehicle with ACC activated relative to a preceding target vehicle. Conventional ACC achieves this using a series of radar sensors that detect the target vehicle's speed and distance and modifying the subject vehicle's speed as necessary to maintain substantially constant following distance.

[0005] Thus, if the target vehicle decelerates, the ACC system, through the use of radar sensors, may detect such deceleration. These radar sensors may communicate this deceleration to the subject vehicle's ECU. The ECU may then, in a vehicle containing a gasoline engine, transmit command signals to throttle valve actuators to adjust degree of throttle valve opening in order to effectuate a corresponding deceleration of the subject vehicle. By contrast, if the ACC in a vehicle containing a gasoline engine detects, through the use of radar sensors, that the target vehicle has moved to a different lane, or that conditions otherwise permit of acceleration, the ECU may then transmit command signals to throttle valve actuators to adjust degree of throttle valve opening in order to effectuate a corresponding acceleration of the subject vehicle up to the pre-set vehicle speed.

[0006] Analogously, in vehicles containing a diesel engine, when a subject vehicle detects that a preceding target vehicle has decelerated, the ECU of the subject vehicle may transmit a command signal to fuel injectors to decrease the volume of fuel injected into engine cylinders of the subject vehicle. Alternatively, when the subject vehicle detects that the target vehicle has switched to a different lane, or that conditions otherwise permit of acceleration, the ECU may then transmit a command signal to fuel injectors to increase the volume of fuel injected into the engine cylinders.

[0007] As those skilled in the art will readily appreciate, in vehicles containing a diesel engine, an engine brake (i.e., a compression brake or an exhaust brake) may be used in tandem with wheel brakes to facilitate deceleration.

[0008] Engine brakes may be particularly useful in heavy trucks as a supplemental way by which to slow the truck. Those skilled in the art understand the essential methods of operation of an engine brake, whether it be a compression brake or an exhaust brake. Generally, to activate a compression brake, a driver of a truck will actuate a switch or similar input aspect to an activated position. Such activation will cause a command signal to be sent to the vehicle's ECU. The ECU will then transmit a command signal to the compression brake to actuate the engine exhaust valves so that they are in an open position thus allowing the air-fuel mixture attendant to operation of an internal combustion engine to be propelled out of the cylinders during what would be the compression stroke. This has the effect of diminishing the force applied to the engine's crankshaft during the power stroke thereby causing deceleration of the vehicle. Those of skill in the art will appreciate that exhaust brakes operate in an opposite manner in that they hold the compressed air-fuel mixture in the cylinder, which has the effect of slowing crankshaft rotation.

[0009] As discussed above, when ACC is active, there are instances when deceleration of the subject vehicle may be required in order to maintain a substantially constant following distance relative to the target vehicle. Different deceleration responses, however, may be required depending on, for example, the slope of the surface on which the subject vehicle is travelling. A vehicle travelling on a downward sloping surface may require a higher degree of engine braking in order to maintain substantially constant following distance than a vehicle travelling on a surface with a positive slope or on a flat or substantially flat surface because of acceleration due to gravity acting upon the subject vehicle when travelling on a downward sloping surface.

[00010] Similarly, different deceleration responses may be required of the ACC system depending on the pitch of the subject vehicle. A vehicle exhibiting a negative pitch may require a higher degree of engine braking than a vehicle exhibiting a positive pitch because of acceleration due to gravity acting upon the subject vehicle exhibiting a negative pitch.

[00011] Accordingly, information pertaining to slope of the surface on which the subject vehicle is travelling and information pertaining to pitch of the subject vehicle may inform identification of a degree of engine braking necessary to maintain substantially constant following distance relative to a target vehicle.

[00012] In vehicles equipped with conventional ACC systems, in order to accurately adjust desired degree of engine braking given a downward sloping surface or a decrease in vehicle pitch (i.e., so as to maintain a substantially constant following distance behind a target vehicle), the system may not be requesting an optimal new degree of engine braking when travelling on an upward sloping surface or a substantially flat surface, or when vehicle pitch increases. This is because conventional ACC systems do not adequately control for factors such as change in slope of a surface and change in pitch of the subject vehicle. Rather, engine braking models programmed into conventional ACC systems are calibrated based on a downward sloping environment and, therefore, may over-compensate with respect to engine braking when the subject vehicle is travelling on an upward sloping or substantially flat surface, or when vehicle pitch increases.

SUMMARY OF THE INVENTION

[00013] An aspect of this disclosure advantageously provides for a system, implementable in a subject vehicle equipped with adaptive cruise control technology, for maintaining a substantially constant following distance relative to a preceding target vehicle, notwithstanding change in slope of a surface on which the subject vehicle is travelling and notwithstanding change in pitch of the subject vehicle. An aspect of this disclosure advantageously provides for such a system wherein, upon receipt of data from sensors on the subject vehicle for detecting driving surface slope and vehicle pitch, an electronic control unit of the subject vehicle identifies a new desired degree of engine braking and, utilizing an engine brake, effectuates a change in the position of engine exhaust valves as necessary to realize the new desired degree of engine braking. An aspect of this disclosure advantageously provides for associated methods of operating the subject vehicle when ACC has been activated utilizing systems of the present disclosure so as to maintain substantially constant following distance relative to a preceding target vehicle.

[00014] According to aspects of systems enabled by this disclosure, slope-detecting sensors as discussed herein may be positioned, without limitation, on a vehicle’s frame within approximately six inches from such vehicle’s transmission and/or within approximately six inches from such vehicle’s wheel well. In instances where systems and methods of the present disclosure are deployed in a truck weighing more than approximately 10,000 pounds, sometimes referred to by those skilled in the art as “heavy trucks,” slope-detecting sensors as discussed herein may be located on the vehicle’s transmission and/or elsewhere on such vehicle’s powertrain. The foregoing positioning is likewise suitable for pitch-detecting sensors contemplated by the present disclosure. Those of skill in the art will readily appreciate alternative suitable locations for placement of such slope-detecting sensors and pitch-detecting sensors.

BRIEF DESCRIPTION OF THE DRAWINGS

[00015] Figure 1 depicts a left side view of a vehicle that is travelling on a substantially flat surface and is equipped with sensors for determining slope of the surface, as contemplated by systems and methods of the present invention.

[00016] Figure 2 depicts a left side view of a vehicle that is travelling on an upward sloping surface and is equipped with sensors for determining slope of the surface, as contemplated by systems and methods of the present invention.

[00017] Figure 3 depicts a left side view of a vehicle that is travelling on a downward sloping surface and is equipped with sensors for determining slope of the surface, as contemplated by systems and methods of the present invention.

[00018] Figure 4 is a flow chart depicting steps of methods according to the present disclosure.

DETAILED DESCRIPTION

[00019] The following disclosure concerns systems and methods, implementable in vehicles equipped with ACC, where the ACC feature is activated, for managing vehicle following distance by managing degree of engine braking in a subject vehicle. Skilled artisans will appreciate additional embodiments of systems and methods of the present disclosure that extend beyond the examples of this disclosure.

[00020] When reading this disclosure, singular forms should be read to contemplate and disclose plural alternatives. Similarly plural forms should be read to contemplate and disclose singular alternatives. Conjunctions should be read as inclusive unless stated otherwise.

[00021] Expressions such as “at least one of A, B, and C” should be read to permit any one of A, B, or C, alone or in combination with the remaining elements. Additionally, such groups may include multiple instances of one or more elements in that group, which may be included with other elements of that group. All numbers, measurements, and values are given as approximations unless expressly stated otherwise.

[00022] Terms and expressions used throughout this disclosure are to be interpreted broadly. Terms are intended to be understood respective to the definitions provided by this specification. Technical dictionaries and common meanings understood within the applicable art are intended to supplement these definitions. In instances where no suitable definition can be determined from the specification or from technical dictionaries, such terms should be understood according to their plain and common meaning. However, any definitions provided by the specification will govern above all other sources.

[00023] Various objects, features, aspects, and advantages described by this disclosure will become more apparent from the following detailed description, along with the accompanying drawings.

[00024] For purposes of clearly describing the components, features, and method steps discussed throughout this disclosure, some frequently used terms will now be defined. The term “subject vehicle,” as it is used throughout this disclosure, shall mean a vehicle containing a diesel engine, equipped with ACC and operating with ACC activated, comprising a system of the present disclosure and/or operating according to a method of the present disclosure. The term “target vehicle,” as it is used throughout this disclosure, shall mean a vehicle located some distance in front of a subject vehicle and with respect to which speed of the subject vehicle is calibrated so as to maintain substantially constant following distance. The term “engine braking,” as it is used throughout this disclosure, shall mean a process involving decreasing the speed at which a subject vehicle’s engine is operating through methods other than wheel braking. The term “engine braking,” as it is used throughout this disclosure, should be understood as encompassing both compression brakes (also referred to by those skilled in the art as compression release brakes or Jake brakes) and exhaust brakes. Consistent with the foregoing, the term “engine brake(s),” as it is used throughout this disclosure, should be understood as encompassing both compression brakes as well as exhaust brakes.

[00025] Various aspects of the disclosure will now be described in detail, without limitation. In the following disclosure, systems and methods for controlling vehicle following distance by managing degree of engine braking in a subject vehicle, will be discussed. Those of skill in the art will appreciate that alternative labeling of the components, features, and method steps may be provided, which is consistent with the scope and spirit of this disclosure. Skilled readers should not view inclusion of any alternative labels as limiting in any way.

[00026] ACC systems are commonly found in many different makes and models of vehicles today. ACC systems in a subject vehicle may be utilized to maintain a substantially constant following distance behind a preceding target vehicle located in front of the subject vehicle. When a subject vehicle equipped with an engine brake and a conventional ACC system that is activated is travelling on a downward sloping surface, the ACC system may increase the desired degree of engine braking to off-set acceleration due to gravity caused by the downward slope of the surface. Such off-set may be necessary to maintain a substantially constant following distance relative to a target vehicle given the increase in speed due to the downward sloping surface. Such increased desired engine braking may be communicated to the ECU.

[00027] Conventional ACC systems, when there is a change in slope of the surface on which the subject vehicle is travelling, request a new desired degree of engine braking that is calibrated to a downward slope. This new requested engine braking is, therefore, not optimal for upward sloping and substantially flat surfaces. Systems and methods of the present disclosure solve this problem by utilizing sensors that are communicatively and operatively connected to the ECU and transmit data to the ECU regarding slope of the surface on which the subject vehicle is travelling. With this information regarding slope of the surface, a more appropriate new desired degree of engine braking may be identified by the ECU when there is a change in slope of the driving surface.

[00028] In an alternative embodiment, systems and methods of the present disclosure comprise a series of sensors that detect pitch of a subject vehicle. When vehicle pitch changes, a new desired degree of engine braking will be identified to off-set forces causing the change in pitch. With this information regarding pitch of the subject vehicle, a more appropriate new desired degree of engine braking may be identified by the ECU when there is a change in pitch than with conventional ACC systems.

[00029] Systems and methods of the present disclosure may be utilized in a subject vehicle. Systems and methods of the present disclosure may be utilized to maintain a substantially constant following distance behind a target vehicle.

[00030] Components of systems of the present disclosure may include, without limitation, an ECU.

[00031] Components of systems of the present disclosure may include, without limitation, radar sensors capable of detecting following distance relative to a target vehicle and capable of detecting speed of the target vehicle. Such sensors may be communicatively and operatively connected to the ECU. Those of skill in the art will readily appreciate suitable locations throughout the subject vehicle for placement of such radar sensors. Without limitation, such radar sensors may be located behind the grill of a subject vehicle.

[00032] Components of systems of the present disclosure may include, without limitation, sensors that are capable of detecting slope of the surface on which the subject vehicle is travelling. Such sensors may be communicatively and operatively connected to the ECU. Such sensors may be located throughout the subject vehicle at any position that is substantially stable when the subject vehicle is being driven. Without limitation, such sensors may be located on a vehicle's frame within approximately six inches from such vehicle's transmission and/or within approximately six inches from such vehicle's wheel well. In instances where systems and methods of the present disclosure are deployed in a truck weighing more than approximately 10,000 pounds (referred to at times by those skilled in the art as a "heavy truck"), slope-detecting sensors as discussed herein may be located on the vehicle's transmission and/or elsewhere on such vehicle's powertrain. Those of skill in the art will readily appreciate alternative suitable locations for placement of the slope-detecting sensors and pitch-detecting sensors discussed herein.

[00033] Components of systems of the present disclosure may include, without limitation, sensors that are capable of detecting degree of exhaust valve opening in the engine of a subject vehicle. Such sensors may be communicatively and operatively connected to the ECU. Those of skill in the art will readily appreciate suitable locations for placement of such sensors.

[00034] Components of systems of the present disclosure may include, without limitation, engine brakes. Those of skill in the art will readily appreciate suitable locations for placement of such engine brakes.

[00035] Systems of the present disclosure, as well as related methods of the present disclosure, are intended to operate in vehicles containing a diesel engine, equipped with an engine brake, and equipped with ACC, when such ACC has been activated.

[00036] According to systems and methods of the present disclosure, and referring to Figures 1-3, when a subject vehicle encounters a change in slope of the surface on which it is travelling, sensors transmit a signal to the ECU communicating data regarding the change in slope of the surface. Based on the data concerning change in road slope received from such sensors, the ECU may calculate a new desired degree of engine braking necessary to maintain substantially constant following distance relative to a target vehicle.

[00037] Upon receipt by the ECU of data indicating a change in road slope, the ECU may calculate a new desired degree of engine braking and may output a command signal to the subject vehicle's engine brake to modify positioning of engine exhaust valves to allow for the desired degree of engine braking. Without limitation, such command signals from the ECU to the engine brake in a subject vehicle may correlate to low, medium, or high degrees of engine braking.

[00038] Such modifications in engine exhaust valve position may be effectuated in order to achieve a new desired degree of engine braking. Such new desired degree of engine braking may be necessary in order to maintain a substantially constant following distance relative to a target vehicle where there has been a change in slope of the surface on which the subject vehicle is travelling.

[00039] In an alternative embodiment, systems of the present disclosure may comprise sensors capable of detecting pitch of the subject vehicle in lieu of or in addition to sensors for detecting slope of a surface on which the subject vehicle is travelling.

[00040] According to such embodiment, when pitch of the subject vehicle changes, sensors located on the subject vehicle transmit a signal to the ECU communicating data concerning the change in vehicle pitch. Such sensors may be located at any position on the subject vehicle that preserves effectiveness of the sensors. Without limitation, such sensors may be positioned as reflected in Figures 1-3. According to aspects of systems enabled by this disclosure, pitch-detecting sensors as discussed herein may be positioned, without limitation, on a vehicle's frame within approximately six inches from such vehicle's transmission and/or within approximately six inches from such vehicle's wheel well. In instances where systems and methods of the present disclosure are deployed in a heavy truck, pitch-detecting sensors as discussed herein may be located on the vehicle's transmission and/or elsewhere on such vehicle's powertrain. Those of skill in the art will readily appreciate alternative suitable locations for placement of such sensors.

[00041] Based on the data concerning change in vehicle pitch, the ECU may calculate a new desired degree of engine braking necessary to maintain substantially constant following distance relative to a target vehicle.

[00042] Upon receipt by the ECU of such vehicle pitch data, the ECU may calculate a new desired degree of engine braking and may output a command signal to the subject vehicle's engine brake to modify positioning of engine exhaust valves to allow for the desired degree of engine braking. Without limitation, such command signals from the ECU to the engine brake in a subject vehicle may correlate to low, medium, or high degrees of engine braking.

[00043] Such modifications in engine exhaust valve position may be effectuated in order to realize a new desired degree of engine braking. Such new degree of engine braking may be necessary in order to maintain a substantially constant following distance relative to a target vehicle where there has been a change pitch of the subject vehicle.

[00044] While various aspects of systems and methods enabled by this disclosure have been described above, the description of this disclosure is intended to illustrate and not limit the scope of the invention. The invention is defined by the scope of the claims and not the illustrations and examples provided in the above disclosure. Skilled artisans will appreciate additional aspects of the systems and methods enabled by this disclosure, which may be realized in alternative embodiments, after having the benefit of the above disclosure. Other aspects, advantages, embodiments, and modifications are within the scope of the claims.

CLAIMS

1. A system, implementable in a subject vehicle equipped with adaptive cruise control technology, for maintaining a substantially constant following distance from a target vehicle comprising:

(a) a diesel engine;

(b) an electronic control unit;

(c) a first set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting following distance relative to the target vehicle and the speed of the target vehicle;

(d) a second set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting slope of a surface on which the subject vehicle is travelling;

(e) a third set of sensors located throughout the engine of the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting degree of engine exhaust valve opening in the subject vehicle; and,

(f) an engine brake;

wherein, when the subject vehicle encounters a change in slope of a surface on which it is travelling, the second set of sensors transmits a signal to the electronic control unit communicating data concerning the change in slope of the surface;

wherein the electronic control unit, based on the data concerning change in slope received from the second set of sensors, calculates a new desired degree of engine braking necessary to maintain substantially constant following distance relative to a target vehicle; and wherein the electronic control unit outputs to the engine brake a command signal to adjust engine exhaust valve position to one that corresponds to the new desired degree of engine braking.

2. The system of claim 1, wherein the engine brake comprises a compression brake.

3. The system of claim 1, wherein the engine brake comprises an exhaust brake.

4. The system of claim 1, wherein the second set of sensors are located on the powertrain of the subject vehicle.

5. The system of claim 4, wherein the second set of sensors are located on the transmission of the subject vehicle.

6. A system, implementable in a subject vehicle equipped with adaptive cruise control technology, for maintaining a substantially constant following distance from a target vehicle comprising:

(a) a diesel engine;

(b) an electronic control unit;

(c) a first set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting following distance relative to the target vehicle and the speed of the target vehicle;

(d) a second set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting pitch of the subject vehicle;

(e) a third set of sensors located throughout the engine of the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting degree of engine exhaust valve opening in the subject vehicle; and

(f) an engine brake;

wherein, when the pitch of the subject vehicle changes, the second set of sensors transmit a signal to the electronic control unit communicating the change in vehicle pitch;

wherein the electronic control unit, based on the data concerning change in vehicle pitch received from the second set of sensors, calculates a new desired degree of engine braking necessary to maintain substantially constant following distance relative to the target vehicle; and

wherein the electronic control unit outputs to the engine brake a command signal to adjust engine exhaust valve position to one that corresponds to the new desired degree of engine braking.

7. The system of claim 6, wherein the engine brake comprises a compression brake.

8. The system of claim 6, wherein the engine brake comprises an exhaust brake.

9. The system of claim 6, wherein the second set of sensors are located on the powertrain of the subject vehicle.

10. The system of claim 9, wherein the second set of sensors are located on the transmission of the subject vehicle.

11. A method, implementable in a subject vehicle equipped with adaptive cruise control technology, for maintaining a substantially constant following distance relative to a preceding target vehicle comprising:

(a) providing a diesel engine;

(b) providing an electronic control unit;

(c) providing a first set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting following distance relative to the target vehicle and the speed of the target vehicle;

(d) providing a second set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting slope of the surface on which the subject vehicle is travelling;

(e) providing a third set of sensors located throughout the engine of the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting degree of engine exhaust valve opening in the subject vehicle;

(f) providing an engine brake; and

(g) activating adaptive cruise control in the subject vehicle;

wherein, when the subject vehicle encounters a change in slope of the surface on which it is travelling, the second set of sensors transmits a signal to the electronic control unit communicating data concerning the change in slope of the surface;

wherein the electronic control unit, based on the data concerning change in slope received from the second set of sensors, calculates a new desired degree of engine braking necessary to maintain substantially constant following distance relative to a target vehicle; and

wherein the electronic control unit outputs to the engine brake a command signal to adjust engine exhaust valve position to one that corresponds to the new desired degree of engine braking.

12. The method of claim 11, wherein the engine brake comprises a compression brake.

13. The method of claim 11, wherein the engine brake comprises an exhaust brake.

14. The method of claim 11, wherein the second set of sensors are located on the

powertrain of the subject vehicle.

15. The method of claim 14, wherein the second set of sensors are located on the transmission of the subject vehicle.

16. A method, implementable in a subject vehicle equipped with adaptive cruise control technology, for maintaining a substantially constant following distance relative to a preceding target vehicle comprising:

(a) providing a diesel engine;

(b) providing an electronic control unit;

(c) providing a first set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting following distance relative to the target vehicle and the speed of the target vehicle;

(d) providing a second set of sensors located throughout the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting pitch of the subject vehicle;

(e) providing a third set of sensors located throughout the engine of the subject vehicle, which are communicatively and operatively connected to the electronic control unit, wherein said sensors are capable of detecting degree of engine exhaust valve opening in the subject vehicle;

(f) providing an engine brake; and

(g) activating adaptive cruise control in the subject vehicle;

wherein, when the pitch of the subject vehicle changes, the second set of sensors transmit a signal to the electronic control unit communicating the change in vehicle pitch;

wherein the electronic control unit, based on the data concerning change in vehicle pitch received from the second set of sensors, calculates a new desired degree of engine braking necessary to maintain substantially constant following distance relative to the target vehicle; and

wherein the electronic control unit outputs to the engine brake a command signal to adjust engine exhaust valve position to one that corresponds to the new desired degree of engine braking.

17. The method of claim 16, wherein the engine brake comprises a compression brake.

18. The method of claim 16, wherein the engine brake comprises an exhaust brake.

19. The method of claim 16, wherein the second set of sensors are located on the powertrain of the subject vehicle.

20. The method of claim 19, wherein the second set of sensors are located on the transmission of the subject vehicle.

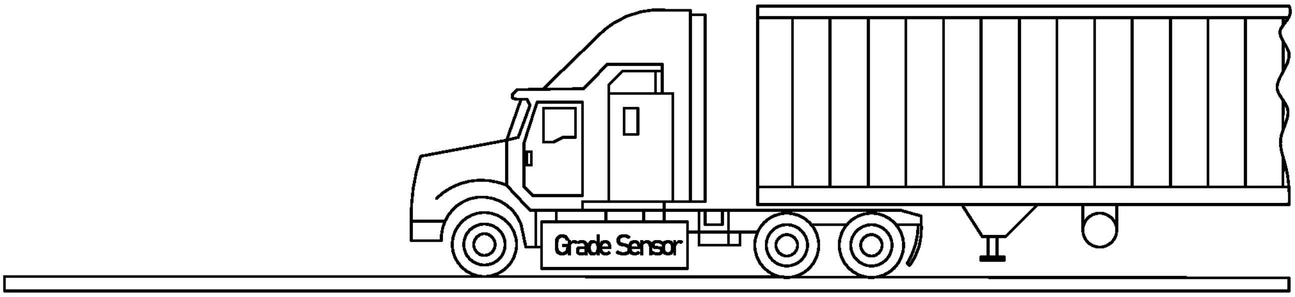

FIG. 1

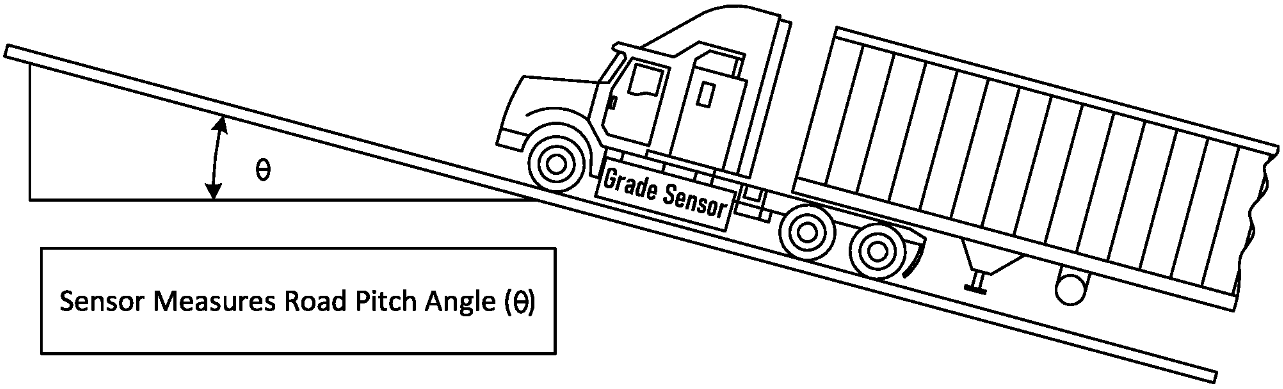

FIG. 2

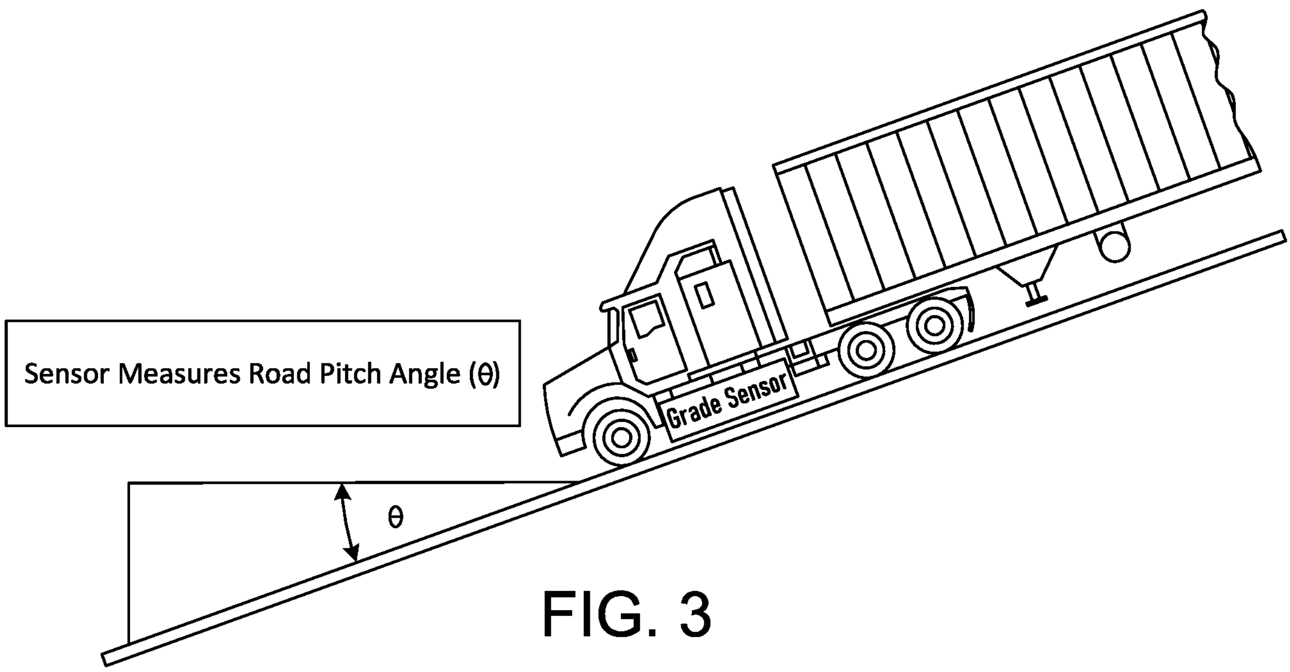

FIG. 3

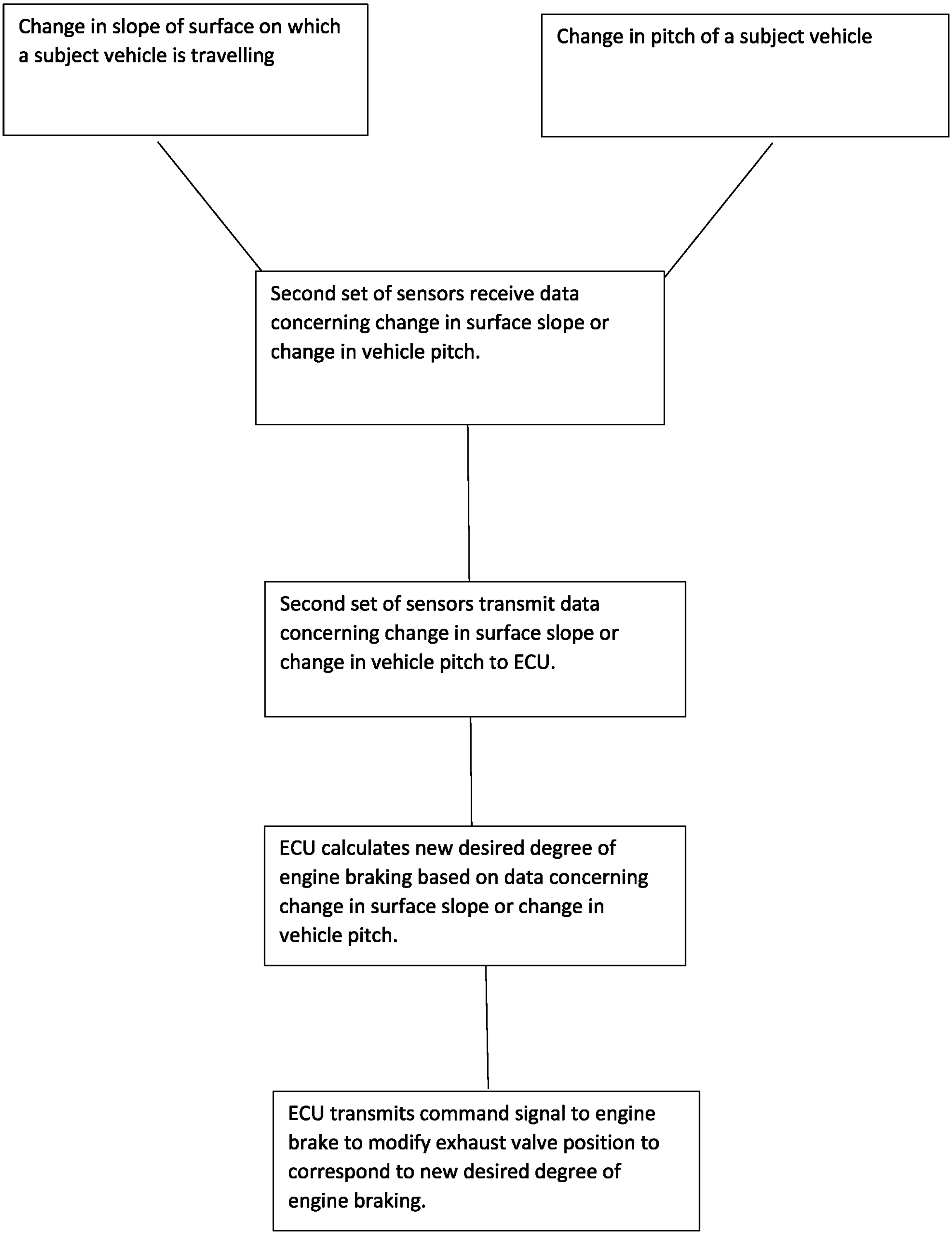
Change in slope of surface on which a subject vehicle is travelling
Change in pitch of a subject vehicle
Second set of sensors receive data concerning change in surface slope or change in vehicle pitch.
Second set of sensors transmit data concerning change in surface slope or change in vehicle pitch to ECU.
ECU calculates new desired degree of engine braking based on data concerning change in surface slope or change in vehicle pitch.
ECU transmits command signal to engine brake to modify exhaust valve position to correspond to new desired degree of engine braking.

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/027308

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60W10/06 B60W10/198 B60W30/16 B60W30/18 F01L13/06
F02D13/04
ADD.

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)
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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2022/169248 A1 (ITO YUTA [JP]) 2 June 2022 (2022-06-02) paragraphs [0017], [0018], [0020], [0023], [0028], [0030], [0033], [0038], [0048]	1-20
A	US 4 359 032 A (OHIE TOMONORI) 16 November 1982 (1982-11-16) column 4	1,6,11, 16
A	US 6 349 253 B1 (BELLINGER STEVEN M [US]) 19 February 2002 (2002-02-19) the whole document	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2023	24/10/2023

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2023/027308

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