(54) Title: VEHICLE STABILITY CONTROL SYSTEM WITH MULTIPLE SENSITIVITIES

(57) Abstract: A system and method for providing stability control for a commercial vehicle. The system may include multiple selectable control tuning modes or sensitivities for defining when the system may intervene to provide corrective action to aid vehicle stability. The control tuning modes may be representative of different vehicle configurations/conditions and a source of input data indicative the present configuration/condition of the vehicle may be provided.
FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Declaration under Rule 4.17:
— of inventorship (Rule 4.17(iv))
VEHICLE STABILITY CONTROL SYSTEM WITH MULTIPLE SENSITIVITIES

Background of the Invention

[0001] Electronic stability control systems are available for use on commercial vehicles such as truck/tractor trailers and buses. These stability systems monitor the dynamic operation of the vehicle and intervene when needed to provide rollover stability or yaw stability.

[0002] Rollover stability counteracts the tendency of a vehicle, or vehicle combination, to tip over while turning. The lateral (side) acceleration during turning creates a force at the center of gravity (CG) of the vehicle, "pushing" the vehicle horizontally. The friction between the tires and the road opposes that force. If the lateral force is high enough, and the tire cornering forces has not yet saturated, the centrifugal force on the CG can create rotational moment at the outer wheels. As a result, one side of the vehicle may begin to lift off the ground potentially causing the vehicle to roll over.

[0003] Yaw stability counteracts the tendency of a vehicle to spin about its vertical axis. During operation, if the friction between the road surface and the vehicle's tires is not sufficient to oppose lateral forces, one or more of the tires can slide, causing the vehicle to spin.

[0004] Electronic stability systems typically utilize an electronic control unit (ECU) that includes system control logic and receives operational information, such as wheel speed, lateral acceleration, yaw rate, and steering angle sensors, from various sensors. The information from these sensors allows the control unit to identify when a stability risk occurs. A single control tuning, which is customized for a particular vehicle family or
platform, is typically uploaded to the system ECU at the vehicle manufacturer. For this particular vehicle platform, the single customized control tuning defines which combinations of sensor readings (i.e. intervention thresholds) will result in the ECU taking corrective action due to a calculated stability risk. If the thresholds are exceeded, the system intervenes to assist the driver in maintaining stability.

[0005] In addition, some stability system logic may be somewhat adaptive. For example, the system may receive operational information on the vehicle load, such as whether the vehicle is hauling an empty trailer or is hauling a loaded trailer. The adaptive aspect of the system may modify the intervention thresholds for a loaded trailer such that the thresholds may be different than the intervention thresholds for an unloaded trailer. Since the system for a particular vehicle platform has a single customized tuning, however, if the operating conditions are the same, the vehicle intervention thresholds will happen in the same manner (i.e. with the same sensitivity).

[0006] In the case of a potential roll event, the system may intervene by overriding the throttle and quickly applying brake pressure at selected wheels to slow the vehicle before the lateral acceleration reaches a critical level. In the case of vehicle slide, the system may reduce the throttle and then brake one or more of the "four corners" of the vehicle (in addition to potentially applying the trailer brakes), thus applying a counter-force to better align the vehicle with an appropriate path of travel.

[0007] Some commercial vehicles, however, may be used in a variety of vehicle configurations or conditions, which may result in different vehicle dynamics. For example, a tractor may need to haul a single trailer for one job and haul a double or triple trailer combination for another job. A tractor hauling a double or triple trailer combination may have more tendency to rollover or slide than a tractor with a single trailer under the same
dynamic conditions. Since the single tuning of the system is optimized for one vehicle configuration or condition, the stability system may not intervene optimally when the vehicle's configuration or condition is changed. Thus, the safety and drivability of the vehicle may be suboptimal when the vehicle configuration/condition is different.

Summary

[0008] The present invention relates generally to a stability system for a vehicle. More particularly, the invention relates to an electronic stability system for a commercial vehicle that may include multiple control tuning modes or sensitivities for defining when the system intervenes to provide corrective action.

[0009] In accordance with one aspect of an apparatus applying principles of the present invention, the system may be adapted to receive input data indicative of a vehicle configuration/condition or estimate the vehicle configuration/condition based on input data. In one embodiment of an apparatus applying principles of the invention, an in-cab manual switch provides input data indicative of a vehicle configuration/condition. In another embodiment, a databus signal may include data indicative of a vehicle configuration/condition. Yet another embodiment, the input data may be indicative of one or more of: the type of trailer being hauled, the type of load being carried, and the position of the center of gravity of the load.

[0010] In accordance with another aspect of a system applying principles of the present invention, the system may include a plurality of control tuning modes. In one embodiment, the plurality of control tuning modes are preprogrammed and stored in the memory of an electronic control unit. In another embodiment, the system may automatically select an appropriate control tuning mode based on input data received by the system. In a more
specific embodiment, a control tuning mode is provided for each of a variety of towed vehicle types being hauled by the commercial vehicle.

[0011] These and other aspects and advantages of the apparatus, systems, and methods applying the principles of the present invention will be apparent to those skilled in the art from the following description of the preferred embodiments in view of the accompanying drawings.

**Brief Description of the Drawings**

[0012] In the accompanying drawing, which are incorporated in and constitute a part of the specification, embodiments of the invention are illustrated, which, together with a general description of the invention given above, and the detailed description given below, serve to exemplify embodiments applying principles of the invention.

[0013] Fig. 1 is a schematic illustration of an exemplary embodiment of a stability system with multiple control tuning modes applying principles of the present invention; and

[0014] Fig. 2 is a flow chart illustrating the control logic of the system of Fig. 1.

**Detailed Description**

[0015] The present invention contemplates a system, apparatus, and method of providing stability control for a commercial vehicle. The invention may include multiple control tuning modes or sensitivities for defining when the system may intervene to provide corrective action to aid vehicle stability. The control tuning modes may be representative of different vehicle configurations/conditions and a source of input data indicative the present configuration/condition of the vehicle may be provided.
While various aspects and concepts of the invention may be described and illustrated herein as embodied in combination in the exemplary embodiments, these various aspects and concepts may be realized in many alternative embodiments, either individually or in various combinations and sub-combinations thereof. Unless expressly excluded herein all such combinations and sub-combinations are intended to be within the scope of the present invention. Still further, while various alternative embodiments as to the various aspects and features of the invention, such as alternative materials, structures, configurations, methods, devices, software, hardware, control logic and so on may be described herein, such descriptions are not intended to be a complete or exhaustive list of available alternative embodiments, whether presently known or identified herein as conventional or standard or later developed. Those skilled in the art may readily adopt one or more of the aspects, concepts or features of the invention into additional embodiments within the scope of the present invention even if such embodiments are not expressly disclosed herein. Additionally, even though some features, concepts or aspects of the invention may be described herein as being a preferred arrangement or method, such description is not intended to suggest that such feature is required or necessary unless expressly so stated. Still further, exemplary or representative values and ranges may be included to assist in understanding the present invention however, such values and ranges are not to be construed in a limiting sense and are intended to be critical values or ranges only if so expressly stated.

Referring to Fig. 1, a schematic representation of a stability system 10 for a commercial vehicle according to principles of the present invention is illustrated. The system 10 may be adapted to detect and monitor a variety of operational parameters and conditions of the commercial vehicle and intervene to take corrective action as needed to maintain stability. In the exemplary embodiment of Fig. 1, the system 10 may include one
or more devices 14 for providing input data indicative of an operating parameter or condition of a commercial vehicle. For example, the devices 14 may be one or more sensors, such as but not limited to, one or more wheel speed sensors 16, a lateral acceleration sensor 18, a steering angle sensor 20, a brake pressure sensor 22, a vehicle load sensor 24, and a yaw rate sensor 26. The system 10 may also utilize additional devices or sensors not described in the exemplary embodiment or combine one or more devices or sensors into a single unit.

[0018] The system 10 may also include a logic applying arrangement 30, such as a controller or processor, in communication with the one or more devices 14. The controller 30 may include one or more inputs for receiving input data from the devices 14. The controller 30 may be adapted to process the input data and compare the raw or processed input data to a stored threshold value. The controller 30 may also include one or more outputs for delivering a control signal to one or more vehicle systems 32 based on the comparison. The control signal may instruct the systems 32 to intervene in the operation of the vehicle to initiate corrective action. For example, the controller 30 may generate and send the control signal to an engine electronic control unit or an actuating device to reduce the engine throttle 34 and slowing the vehicle down. Further, the controller 30 may send the control signal to a vehicle brake system to selectively engage the brakes. In a tractor-trailer arrangement, the controller 30 may engage the brakes on one or more wheels of a trailer portion of the vehicle 36 and the brakes on one or more wheels of a tractor portion of the vehicle 38. A variety of corrective actions may be possible and multiple corrective actions may be initiated at the same time.

[0019] The controller 30 may also include a memory portion 40 for storing and accessing system information, such as for example the system control logic and control tuning. The
memory portion 40, however, may be separate from the controller 30. The sensors 14 and controller 30 may be part of a preexisting system or use components of a preexisting system. For example, the Bendix® ABS-6 Advanced Antilock Brake Controller with ESP® Stability System available from Bendix Commercial Vehicle Systems, LLC may be installed on the vehicle. The Bendix ESP system may utilize some or all of the sensors described in Fig. 1. The logic component of the Bendix ESP system resides on the vehicle's antilock brake system electronic control unit, which may be used for the controller 30 of the present invention. Therefore, many of the components to support the system 10 of the present invention may be present in a vehicle equipped with the Bendix ESP system, thus, not requiring the installation of additional components. The system 10, however, may utilize independently installed components if desired.

[0020] The system 10 may also include a source of input data 42 indicative of a configuration/condition of a commercial vehicle. The controller 30 may sense or estimate the configuration/condition of the vehicle based on the input data, and may select a control tuning mode or sensitivity based on the vehicle configuration/condition. The controller 30 may compare the operational data received from the sensors 14 to the information provided by the tuning. The tuning of the system may include, but not be limited to: the nominal center of gravity height of the vehicle, look-up maps for lateral acceleration level for rollover intervention, look-up maps for yaw rate differential from expected yaw rate for yaw control interventions, steering wheel angle allowance, tire variation allowance, and brake pressure rates, magnitudes and maximums to applied during corrective action.

[0021] A vehicle configuration/condition may refer to a set of characteristics of the vehicle which may influence the vehicle's stability (roll and/or yaw). For example, in a vehicle with a towed portion, the source of input data 42 may communicate the type of towed
portion. In tractor-trailer arrangements, the type of trailer being towed by the tractor may influence the vehicle stability. This is evident, for example, when multiple trailer combinations (doubles and triples) are towed. Vehicles with multiple trailer combinations may exhibit an exaggerated response of the rearward units when maneuvering (i.e. rearward amplification). To compensate for rearward amplification, the stability system 10 may select a tuning that makes the system more sensitive (i.e. intervene earlier than would occur for a single trailer condition). The control tuning may be, for example, specifically defined to optimize the performance of the stability system for a particular type of trailer being hauled by a particular type of tractor. Thus, the control tuning may be different for the same tractor hauling a single trailer, a double trailer combination, or a triple trailer combination.

[0022] The type of load the commercial vehicle is carrying and the location of the center of gravity of the load may also influence vehicle stability. For example, moving loads such as liquid tankers with partially filled compartments and livestock may potentially affect the turning and rollover performance of the vehicle. Thus, a more sensitive control tuning mode may be selected to account for a moving load. Furthermore, a separate control tuning mode may be selectable when the vehicle is transferring a load whose center of gravity is particularly low or particularly high, such as for example with certain types of big machinery or low flat steel bars.

[0023] Fig. 2 illustrates a flow chart of an example of a control logic for the stability system of Fig. 1. Upon vehicle start-up 100, the system 10 may select a default control tuning mode 102 from multiple, selectable tuning modes stored in the memory 40 of the system for different types of vehicle configurations or load types. A default tuning mode may be preprogrammed into the logic of the system 10 based on the configuration/condition that the vehicle normally operates in. For example, if the vehicle typically hauls a single trailer with
a stationary, centered load, then the tuning mode for the system 10 may be optimized for that particular configuration/condition and set as the default tuning mode for the system.

[0024] The system 10 may also check the configuration/condition of the vehicle 104 to determine if the control tuning mode should remain as the default mode or should be changed to another control tuning mode. The system 10 may accomplish this by receiving input data indicative of a vehicle configuration/condition from one or more sources of input data 42. Examples of possible sources for the input data may include, but not be limited to, a manual switch in the cab of the vehicle, a databus message from J2497 power line carrier (PLC) on a trailer or J1939 Controller Area Network (CAN), one or more sensors adapted to provide input data indicative of a vehicle condition, or other possible input data sources. Furthermore, the controller 12 may utilize an estimation algorithm to estimate a vehicle configuration/condition based on one or more vehicle parameters instead of or in combination with any of the methods described above.

[0025] If the system 10 determines that the vehicle configuration/condition dictates a change in the control tuning mode, the controller 12 may select one of the multiple control tuning modes stored in memory 40. For example, if the input data indicates that a two trailer combination is being used, the system 10 may select a tuning mode optimized for a two trailer combination. One of ordinary skill in the art will appreciate that the system 10, based on the amount of memory 40 available, may be preprogrammed with as many control tuning modes as desired to reflect various vehicle configurations/conditions.

[0026] Once the control tuning mode has been selected, the system 10 may determine the rollover intervention thresholds and yaw control intervention thresholds 110 based on the control tuning mode. These thresholds may then be activated in the stability control
algorithm and the control algorithm applied so that when the thresholds are exceeded or predicted to be exceeded, the system 10 will intervene to maintain vehicle stability.

[0027] The system 10 may also be programmed to repeatably check for a vehicle condition change. Thus, the system 10 may determine if the vehicle ignition is ON. If the ignition is OFF, then control logic may END. If, however, the vehicle ignition is ON, then system 10 may loop back to the logic step of checking the vehicle condition. For example, the system 10 may include devices to detect if the vehicle load has changed or shifted. Different control tuning may be defined for a stationary load versus a movable load or a centered load versus an offset load. Therefore, the system 10 may select an appropriate control tuning mode for the configuration/condition detected. For example, more sensitive tuning may be selected to address a movable load or different tunings may be used in a delivery vehicle as the load changes as portions are unloaded at a plurality of delivery locations.

[0028] The invention has been described with reference to the preferred embodiments. Modification and alterations will occur to others upon a reading and understanding of this specification. It is intended to include all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.
Claims

1. A controller for aiding the stability control of a commercial vehicle, the controller comprising:

   one or more inputs for receiving configuration data indicative of a configuration of the vehicle;

   one or more inputs for receiving operational data indicative of a stability risk;

   a logic applying arrangement for selecting one of a plurality of control tuning modes based on the configuration data received, the logic applying arrangement adapted to determine one or more intervention thresholds based on the selected control tuning mode, wherein the logic applying arrangement compares the operational data to the one or more intervention thresholds and generates a control signal representative of a corrective action as a function of the comparison; and

   an output for sending the control signal to an operational system of the vehicle for initiating the corrective action.

2. The controller of claim 1 wherein the corrective action includes braking the vehicle.

3. The controller of claim 1 wherein the corrective action includes reducing throttling of an engine of the vehicle.

4. The controller of claim 1 further comprising a memory portion for storing the plurality of control tuning modes.

5. The controller of claim 1 wherein the operational data includes one or more of: lateral acceleration data, yaw rate data, wheel speed data, and steering angle data.
6. The controller of claim 1 wherein the commercial vehicle includes a towed vehicle, and wherein the input receives configuration data indicative of the type of the vehicle being towed.

7. The controller of claim 1 wherein the commercial vehicle includes a load being hauled, and wherein the input receives configuration data indicative of the location of the center of gravity of the load.

8. A controller for improving the stability of a commercial vehicle, the controller comprising:

   a means for receiving input data indicative of a configuration of the vehicle;

   a means for receiving operational data indicative of a stability risk of the vehicle;

   a processing means for analyzing the input data and selecting one of a plurality of control tuning modes based on the input data, the processing means adapted to compare the operational data to one or more threshold values defined by the selected control tuning mode, wherein the processing means is adapted to generate a control signal representative of a corrective action based on the comparison between the operational data and the one or more threshold values; and

   a means for sending the control signal to an operational system of the vehicle for initiating the corrective action.

9. The controller of claim 8 further comprising a means for storing the plurality of control tuning modes.

10. The controller of claim 8 wherein the commercial vehicle includes a towed vehicle, and wherein the configuration of the vehicle includes the type of vehicle being towed.

11. The controller of claim 8 wherein the corrective action includes braking the vehicle.
12. A stability control system for a commercial vehicle, the system comprising:

   a source of input data indicative of a vehicle configuration;
   a memory portion for storing two or more selectable sensitivities for the system;
   a controller in communication with the source of input data and the memory portion, the controller adapted to receive the input data and select one of the two or more system sensitivities from the memory portion based on the input data; and
   a device in communication with the controller for sending operational data to the controller, wherein the controller is adapted to analyze the operational data to determine if a stability risk exists and to send a control signal to an operational system of the vehicle for initiating a corrective action based on the determination.

13. The stability control system of claim 12 wherein the commercial vehicle includes one or more towed vehicles, and wherein the vehicle configuration includes the type of vehicle being towed.

14. The stability control system of claim 12 wherein the commercial vehicle includes a load being hauled, and wherein the vehicle configuration includes the location of the center of gravity of the load.

15. The stability control system of claim 12 wherein the source of input data is at least one of: a manual switch, a databus message, a driving condition estimation algorithm, and one or more sensors capable of sensing the type of vehicle being towed.

16. The stability control system of claim 12 wherein the memory portion is integral to the controller.

17. The stability control system of claim 12 wherein the controller is a vehicle antilock brake system electronic control unit.
18. The stability control system of claim 12 wherein the corrective action includes applying a brake on one or more wheels of the vehicle.

19. A stability control system for a vehicle having a towed portion, the system comprising:

   a device for sending a configuration signal indicative of the configuration of the towed portion;

   one or more sensors for sensing a stability risk of the vehicle;

   a memory portion for storing a plurality of selectable control tuning modes;

   a processor in communication with the device for sending a configuration signal, the one or more sensors, and the memory portion, the processor adapted to receive the configuration signal and select one of the plurality of selectable control tuning modes based on the configuration signal, the processor further adapted to generate a control signal in response to input from the one or more sensors of a sensed stability risk of the vehicle; and

   a vehicle brake system in communication with the processor, the vehicle brake system adapted to apply a brake on one or more wheels of the vehicle in response to the control signal.

20. The stability control system of claim 19 wherein the processor is an antilock brake system electronic control unit.

21. The stability control system of claim 19 wherein the device for sending a signal indicative of the configuration of the towed portion is a manual switching device.

22. A method for providing stability control for a commercial vehicle, the method comprising the steps of:

   receiving input data indicative of a vehicle configuration;
selecting one of a plurality of stored control tuning modes based on the input data;
implementing the selected control tuning mode; and
sending a control signal representative of a corrective action.

23. The method of claim 22 further comprising the steps of:
determining one or more intervention thresholds based on the selected control tuning mode;
receiving operational data indicative of a vehicle stability risk;
comparing the operational data to the one or more intervention thresholds;
wherein the step of sending a control signal is based on the step of comparing the operational data to the one or more intervention thresholds.

24. The method of claim 22 further comprising the step of applying a brake on one or more wheels of a vehicle in response to the control signal.

25. The method of claim 22 further comprising the step of actuating a throttle to reduce the speed of the vehicle in response to the control signal.

26. The method of claim 22 wherein the vehicle configuration includes the type of vehicle being towed.
Fig. 1
START-UP 100

SELECT DEFAULT CONTROL TUNING MODE 102

ECU INTERNAL CALCULATIONS 104

CHECK VEHICLE CONDITION

INPUT DATA SOURCES 42

DIFFERENT CONTROL TUNING MODES 40

YES

CHANGE THE CONTROL TUNING MODE?

SELECT THE NEW STABILITY CONTROL TUNING FOR THE VEHICLE 108

DETERMINE ROLLOVER INTERVENTION THRESHOLDS.
DETERMINE YAW CONTROL INTERVENTION THRESHOLDS.

APPLY STABILITY CONTROL ALGORITHM 112

VEHICLE IGNITION STILL 'ON'?

YES

END 116

NO

Fig. 2
INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/006341

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60T8/17 B60T8/172 B60T8/1755 B60T8/24 B60W30/02
ADD. B60W40/12 B60W10/04 B60W10/18

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)
B60T B60W

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

Electronic database consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C

See patent family annex

Date of the actual completion of the international search
24 July 2007

Date of mailing of the international search report
31/07/2007

Name and mailing address of the ISA:
European Patent Office P B 5818 Patentlaan 2 NL - 2380 HV Rijswijk Tel (+31-70) 340-0340 Tx 31 651 epo nl, Fax (+31-70) 340-3016

Authorized officer
Marx, Winfried
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