United States Patent Application Publication	20250263012
Kind Code	A1
Publication Date	August 21, 2025
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VEHICLE APPROACH NOTIFICATION DEVICE

Abstract

The vehicle approach notification device includes a sound pressure control unit that controls the sound pressure of an approach notification sound outputted from a sound generator provided in electrified vehicle toward the outside of the vehicle in accordance with the vehicle speed of electrified vehicle. The sound pressure control unit is configured to control such that, when the vehicle speed of electrified vehicle is larger than the threshold-value vehicle speed, the sound pressure of the approach notification sound gradually decreases as the vehicle speed of electrified vehicle increases.

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Appl. No.: **18/954898**

Filed: **November 21, 2024**

Foreign Application Priority Data

JP	2024-022223	Feb. 16, 2024

Publication Classification

Int. Cl.: **B60Q5/00** (20060101)

U.S. Cl.:

CPC **B60Q5/008** (20130101);

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-022223 filed on Feb. 16, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The present specification discloses an improvement of a vehicle approach notification device.

2. Description of Related Art

[0003] An electrified vehicle such as a battery electric vehicle or a hybrid electric vehicle travels using a driving force of a motor during low-speed travel. Thus, unlike the engine-driven vehicle, the electrified vehicle does not emit much noise during low-speed travel. Therefore, it may be difficult for a person (e.g., a pedestrian) around the electrified vehicle to notice that the electrified vehicle is nearby. Thus, conventionally, the electrified vehicle outputs an approach notification sound toward the outside of the vehicle during low-speed travel, in order to allow a person around the electrified vehicle to notice that the electrified vehicle is nearby. It is stipulated in the laws and regulations of each country that the electrified vehicle must output an approach notification sound toward the outside of the vehicle during low-speed travel.

[0004] Conventionally, there has been proposed a technique of controlling the output of an approach notification sound. For example, Japanese Unexamined Patent Application Publication No. 2012-121518 (JP 2012-121518 A) discloses a vehicle approach notification device including a speaker that outputs an approach notification sound toward the outside of the vehicle. The vehicle approach notification device changes the pitch (frequency, i.e., tone) of the approach notification sound to be output from the speaker according to the vehicle speed of the electrified vehicle. Further, the vehicle approach notification device changes the output level of the approach notification sound output from the speaker according to the pitch of the approach notification sound.

SUMMARY

[0005] As the vehicle speed of the electrified vehicle increases, noise (background noise) emitted from the electrified vehicle increases. Thus, in the laws and regulations of each country, it is stipulated that the electrified vehicle should output an approach notification sound during low-speed travel. In other words, the law does not stipulate that the electrified vehicle must output an approach notification sound during high-speed travel. Thus, when the vehicle speed of the electrified vehicle increases, there is no need to output an approach notification sound according to the law. Therefore, the electrified vehicle stops the approach notification sound when the vehicle speed becomes equal to or higher than a predetermined vehicle speed.

[0006] Here, when the approach notification sound is stopped, a person around the electrified vehicle or an occupant may feel uncomfortable (be surprised or the like). This will be described in detail with reference to FIG. **4**.

[0007] FIG. **4** is a graph illustrating the relationship between the vehicle speed and the sound pressure of the approach notification sound in the conventional electrified vehicle. In the graph of FIG. **4**, the horizontal axis represents the vehicle speed of the electrified vehicle, and the vertical axis represents the sound pressure of the approach notification sound output from the electrified vehicle or the background noise. When the vehicle speed is less than 0, it is meant that the electrified vehicle is traveling in reverse. In the example of FIG. **4**, the unit of the sound pressure is [dBA], that is, the sound pressure is represented by the A-weighted sound pressure level. Here, the sound pressure is a sound pressure at predetermined positions from the electrified vehicle, as

prescribed by the laws and regulations. For example, the law stipulates that the sound pressure should be a sound pressure at two positions at a height of 1.2 meters, 2 meters to the left and 2 meters to the right from the position of the front end of the electrified vehicle and the center in the vehicle width direction. Therefore, the sound pressure in FIG. **4** also indicates the sound pressure at such positions.

[0008] A point Pa, a point Pb, and a point Pc indicated in FIG. **4** represent the vehicle speed and the sound pressure of the approach notification sound stipulated by the law. For example, in the law represented by the point Pa, it is stipulated that an approach notification sound having a sound pressure of La or higher should be output when the vehicle speed of the electrified vehicle is Va (when the electrified vehicle is traveling in reverse at the vehicle speed Va since Va is less than 0). In the law represented by the point Pb, it is stipulated that an approach notification sound having a sound pressure of Lb or higher should be output when the vehicle speed of the electrified vehicle is Vb. In the law represented by the point Pc, it is stipulated that an approach notification sound having a sound pressure of Lc or higher should be output when the vehicle speed of the electrified vehicle is Vc. The vehicle speed Vc is higher than the vehicle speed Vb, and the sound pressure Lc is higher than the sound pressure Lb. That is, the law requires that an approach notification sound having a higher sound pressure should be output as the vehicle speed of the electrified vehicle increases.

[0009] The solid line in FIG. **4** indicates the relationship between the vehicle speed of the electrified vehicle and the sound pressure of the approach notification sound output from the electrified vehicle. For example, in the electrified vehicle, an approach notification sound having a sound pressure corresponding to the vehicle speed is output so as to meet the law represented by the point Pa, the point Pb, and the point Pc. Specifically, when the vehicle speed of the electrified vehicle is the vehicle speed Va, an approach notification sound having the sound pressure La or higher is output. When the vehicle speed of the electrified vehicle is the vehicle speed Vb, an approach notification sound having the sound pressure Lb or higher is output. When the vehicle speed of the electrified vehicle is the vehicle speed Vc, an approach notification sound having the sound pressure Lc or higher is output. According to the law, when the vehicle speed of the electrified vehicle is higher than 0, the sound pressure of the approach notification sound increases as the vehicle speed of the electrified vehicle increases.

[0010] In the present specification, the highest vehicle speed among a plurality of vehicle speeds prescribed by the law is referred to as a statutory maximum vehicle speed. In the example of FIG. **2**, the statutory maximum vehicle speed is the vehicle speed Vc (in this case, indicated as the statutory maximum vehicle speed Vc). The law does not require that an approach notification sound should be output when the vehicle speed of the electrified vehicle is higher than the statutory maximum vehicle speed Vc. Thus, the electrified vehicle may stop outputting the approach notification sound when the vehicle speed of the electrified vehicle is higher than the statutory maximum vehicle speed Vc. In the example of FIG. **4**, the electrified vehicle stops outputting the approach notification sound (sets the sound pressure of the approach notification sound to 0 [dBA]) at a speed Vp**1** (Vp**1**>statutory maximum vehicle speed Vc), which has a slight margin from the statutory maximum vehicle speed Vc.

[0011] When the output of the approach notification sound is stopped at the vehicle speed Vp**1**, the approach notification sound that has been output at the sound pressure of Lc or higher is suddenly stopped. Consequently, a person around the electrified vehicle may feel uncomfortable.

[0012] The broken line in FIG. **4** indicates the relationship between the vehicle speed of the electrified vehicle and the sound pressure of the background noise. Here, the background noise is a sound emitted from the electrified vehicle other than the approach notification sound, and includes a motor sound of the electrified vehicle, road noise, etc., for example. As indicated in FIG. **4**, the sound pressure of the background noise increases as the vehicle speed increases. Even if the approach notification sound is suddenly stopped, it is less likely that a person around the electrified

vehicle feels uncomfortable because of the presence of the background noise. That is, the background noise acts to reduce a sense of discomfort felt by a person around the electrified vehicle when the approach notification sound is stopped. However, if a difference ALI between the sound pressure of the approach notification sound at the vehicle speed Vp**1** (immediately before stop) and the sound pressure of the background noise at the vehicle speed Vp**1** is large, a person around the electrified vehicle still feels uncomfortable.

[0013] The present disclosure provides a vehicle approach notification device capable of reducing a sense of discomfort felt by a person around an electrified vehicle by stopping an approach notification sound output from the electrified vehicle.

[0014] An aspect of the present disclosure provides a vehicle approach notification device including

a sound pressure control unit that controls a sound pressure of an approach notification sound output from a sound generator provided in an electrified vehicle toward outside of the vehicle according to a vehicle speed of electrified vehicle, in which

the sound pressure control unit is configured to perform control such that the sound pressure of the approach notification sound gradually decreases as the vehicle speed of electrified vehicle increases when the vehicle speed of the electrified vehicle is higher than a threshold vehicle speed.

[0015] The sound pressure control unit may be configured to stop output of the approach notification sound from the sound generator when a difference between the sound pressure of the approach notification sound and a sound pressure of background noise becomes equal to or less than a threshold sound pressure as a result of the sound pressure of the approach notification sound gradually decreasing as the vehicle speed of the electrified vehicle increases.

[0016] According to the vehicle approach notification device of the present disclosure, it is possible to reduce a sense of discomfort felt by a person around an electrified vehicle by stopping an approach notification sound output from the electrified vehicle.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0018] FIG. **1** is a configuration schematic diagram of a vehicle approach notification device according to the present embodiment;

[0019] FIG. **2** is a diagram showing the contents of a sound pressure control function showing the relationship between the vehicle speed and the sound pressure of the approach notification sound in the present embodiment;

[0020] FIG. **3** is a flow chart showing a flow of a process of creating a sound pressure control function; and

[0021] FIG. **4** is a graph showing the relation between the vehicle speed and the sound pressure of the approach notification sound in the conventional electrified vehicle.

DETAILED DESCRIPTION OF EMBODIMENTS

[0022] FIG. **1** is a configuration schematic diagram of a vehicle approach notification device **10** according to the present embodiment. The vehicle approach notification device **10** is provided at least in an electrified vehicle EV where the vehicle travels with the driving force of the motor during low-speed traveling. Electrified vehicle EV is a battery electric vehicle, a hybrid electric vehicle, or the like. The vehicle approach notification device **10** includes a vehicle speed sensor **12**, a memory **14**, a speaker **16**, and an ECU **18**. ECU **18** is communicably connected to the vehicle speed sensor **12**, the memories **14**, and the speakers **16**.

[0023] The vehicle speed sensor **12** is a sensor that detects the vehicle speed of electrified vehicle EV. For example, the vehicle speed sensor **12** detects the vehicle speed by detecting the rotational speed of the output shaft of the transmission. The vehicle speed sensor **12** may be any sensor as long as electrified vehicle EV vehicle speed can be detected. The vehicle speed detected by the vehicle speed sensor **12** is inputted to ECU **18**.

[0024] The memories **14** are configured to include Solid State Drive (SSD), embedded Multi Media Card (eMMC), Read Only Memory (ROM), or Random Access Memory (RAM). The memory **14** stores a vehicle approach notification program for operating each unit of the vehicle approach notification device **10**. The approach notification program may be stored in a non-transitory computer-readable storage medium such as a USB memory or a SD card. The vehicle approach notification device **10** can read and execute the vehicle approach notification program from such a storage medium.

[0025] The sound source file **14***a* and the sound pressure control function **14***b* are stored in the memory **14**. The sound source file **14***a* is a sound data representing an approach notification sound. The sound pressure control function **14***b* is a function indicating a relation between the vehicle speed of electrified vehicle EV and the sound pressure of the approach notification sound outputted from electrified vehicle EV. The sound pressure control function **14***b* will be described later.

[0026] The speaker **16** serving as a sound generator outputs an approach notification sound toward the outside of the vehicle at a sound pressure in accordance with control from ECU **18**, based on control from ECU **18**. In the present embodiment, the speaker **16** outputs the sound obtained by reproducing the sound source file **14***a* to the outside of the vehicle as an approach notification sound. The sound generator is not limited to the speaker **16** as long as the sound pressure of the approaching notification sound to be outputted can be changed by control from ECU **18**, and may be, for example, a piezoelectric sounder, a buzzer, or the like.

[0027] ECU **18** includes, for example, a processor and peripheral components thereof. ECU **18** controls the sound pressure of the approach notification sound outputted from the speaker **16** in accordance with the vehicle-approach notification program stored in the memory **14**. Specifically, ECU **18** controls the sound pressure of the approach notification sound outputted from the speaker **16** by controlling the amplitude of the voltage of the audio signal which is an electric signal supplied to the speaker **16**. In particular, ECU **18** controls the sound pressure of the approach notification sound outputted from the speaker **16** according to the vehicle speed of electrified vehicle EV detected by the vehicle speed sensor **12**. That is, ECU **18** functions as a sound pressure control unit.

[0028] FIG. **2** is a diagram showing the content of the sound pressure control function **14***b* showing the relation between the vehicle speed and the sound pressure of the approach notification sound in the present embodiment. In the present embodiment, ECU **18** controls the sound pressure of the approach notification sound outputted from the speaker **16** in accordance with the sound pressure control function **14***b*. The sound pressure control function **14***b* is created in advance by a designer of the vehicle approach notification device **10** and stored in the memories **14**. In the present embodiment, the sound pressure control function **14***b* is a graph as shown in FIG. **2**. However, the sound pressure control function **14***b* may be any type of function as long as it indicates the relation between the vehicle speed of electrified vehicle EV and the sound pressure of the approach notification sound.

[0029] In FIG. **2**, similarly to FIG. **4**, the horizontal axis represents the vehicle speed of electrified vehicle EV, and the vertical axis represents the sound pressure of the approaching notification sound or the background noise outputted from electrified vehicle EV. The sound pressure in FIG. **2** also indicates the sound pressure at a predetermined position with respect to electrified vehicle EV, which is stipulated by laws and regulations. That is, the predetermined position is, for example, two positions in the height 1.2 meters from the position of the vehicle front end and the vehicle width-direction center of electrified vehicle EV to the left by 2 meters and the right by 2 meters.

[0030] As in the related art, ECU **18** controls the sound pressure of the approach notification sound in accordance with the vehicle speed so as to satisfy the legal regulations represented by a plurality of point Pa,Pb,Pc. At least, ECU **18** controls such that the sound pressure of the approaching notification sound increases as the vehicle speed increases so as to satisfy the law in a speed range equal to or lower than the maximum vehicle speed Vc of the law.
[0031] ECU **18** controls the sound pressure of an approach notification sound that differs from a conventional one in a velocity range larger than the legal maximal vehicle speed Vc. Conventionally, as shown in FIG. **4**, the approach notification sound is stopped at a vehicle speed Vp**1** which is a vehicle speed larger than the legal maximum vehicle speed Vc. On the other hand, in the present embodiment, ECU **18** performs control such that the sound pressure of the approach notification sound gradually decreases as the vehicle speed of electrified vehicle EV increases when the vehicle speed of electrified vehicle EV is larger than the vehicle speed V**1** as the threshold vehicle speed that is the vehicle speed equal to or higher than the legal maximum vehicle speed Vc. This is determined between the vehicle speed V**1** and the vehicle speed V**2** in FIG. **2**.
[0032] Further, ECU **18** performs the following control because the sound pressure of the approach notification sound gradually decreases as the vehicle speed of electrified vehicle EV increases from the vehicle speed V**1**. That is, ECU **18** stops outputting the approach notification sound from the speaker **16** when the difference between the sound pressure of the approach notification sound and the sound pressure of the background noise (ΔL**2** in FIG. **2**) becomes equal to or lower than the threshold sound pressure (when the vehicle speed of electrified vehicle EV becomes the vehicle speed V**2** in FIG. **2**). Thereafter, in the velocity range larger than the vehicle speed V**2**, ECU **18** does not output an approach notification sound from the speaker **16**.
[0033] Hereinafter, referring to FIG. **2**, the sound pressure control function **14***b* will be described in detail along with the flow of the process of creating the sound pressure control function **14***b* in accordance with the flow chart of FIG. **3**. The details of the sound pressure control function **14***b* are details of the control of the sound pressure of the approach notification sound according to the vehicle speed of electrified vehicle EV by ECU **18**.
[0034] In S**10**, in the velocity range equal to or lower than the legal maximum vehicle speed Vc, the relation between the vehicle speed of electrified vehicle EV and the sound pressure of the approach notification sound is determined so as to satisfy the legal regulations in the same manner as in the related art. Specifically, as the vehicle speed of electrified vehicle EV increases, the sound pressure of the approach notification sound also increases.
[0035] In S**12**, a vehicle speed V**1** larger than the statutory largest vehicle speed Vc is determined. As shown in FIG. **2**, in the sound pressure control function **14***b*, the vehicle speed V**1** is the vehicle speed (V**1**>the regulated maximum vehicle speed Vc) that takes a margin with respect to the regulated maximum vehicle speed Vc, but the vehicle speed V**1** may be larger than the regulated maximum vehicle speed Vc. Then, the sound pressure L**1** of the approach notification sound in the vehicle speed V**1** is determined. The sound pressure L**1** is set to a sound pressure (L**1**≥Lc) equal to or higher than the sound pressure Lc at the maximum vehicle speed Vc. A point represented by the vehicle speed V**1** and the sound pressure L**1** in the sound pressure control function **14***b* is referred to as a point P**1**.
[0036] In S**14**, a candidate value of the vehicle speed V**2** which is a vehicle speed larger than the vehicle speed V**1** and is a vehicle speed at which the approach notification sound is stopped, and a candidate value of the sound pressure L**2** of the approach notification sound at the vehicle speed V**2** are determined. The vehicle speed V**2** candidates may be larger than the vehicle speed V**1**. However, when the difference between the vehicle speed V**2** and the vehicle speed V**1** is small, as the vehicle speed of electrified vehicle EV changes from the vehicle speed V**1** to the vehicle speed V**2**, the sound pressure of the approach notification sound rapidly decreases from the sound pressure L**1**, and the output of the approach notification sound is stopped at the vehicle speed V**2**. Therefore, the effect of the present disclosure is reduced. Therefore, the candidate value of the

vehicle speed V**2** is determined such that the difference between the vehicle speed V**2** and the vehicle speed V**1** is equal to or greater than the predetermined value. In the present embodiment, the vehicle speed V**2** candidates are determined such that differences between the vehicle speed V**1** and the vehicle speed V**2** are approximately 15 [km/h] to 20 [km/h], for example.

[0037] Next, candidates for sound pressure L**2** are determined. The sound pressure L**2** candidates are sound pressures that are smaller than the sound pressure L**1**. In particular, the candidate value of the sound pressure L**2** is determined such that the difference ΔL**2** between the candidate value of the sound pressure L**2** and the sound pressure of the background noise in the vehicle speed V**2** is equal to or lower than the threshold sound pressure. The threshold sound pressure may be, for example, 5 [dBA].

[0038] Here, as described above, the background noise is a sound other than the approach notification sound emitted by electrified vehicle EV, and includes, for example, a motor sound of electrified vehicle EV, a road noise, and the like. Also in FIG. **2**, the relation between the vehicle speed of electrified vehicle EV and the sound pressure of the background noise is indicated by a broken line. The sound pressure of background noise increases as the vehicle speed increases. Therefore, the larger the vehicle speed V**2**, the larger the candidate value of the sound pressure L**2**, and conversely, the smaller the vehicle speed V**2**, the smaller the candidate value of the sound pressure L**2**.

[0039] Sensory testing is performed in S**16**. The sensory test is a test for stopping the approach notification sound based on the candidate value of the vehicle speed V**2** and the candidate value of the sound pressure L**2** determined by S**14** and determining whether or not the human (examiner) actually feels uncomfortable around electrified vehicle EV. When the examiner feels uncomfortable (FAILED in S**16**) as a result of the sensory test, S**18** is returned, and the sound pressure L**2** candidates are adjusted. Specifically, in order to make the difference ΔL**2** smaller, the sound pressure L**2** candidates are adjusted to be smaller. In addition, in S**18**, the candidate value of the vehicle speed V**2** may be adjusted in addition to the candidate value of the sound pressure L**2** so as to further reduce the difference ΔL**2**. If the sensory test reveals that the examiner does not feel uncomfortable (OK in S**16**), S**20** proceeds.

[0040] In S**20**, the candidate value of the vehicle speed V**2** and the candidate value of the sound pressure L**2** determined by S**14** or the candidate value of the vehicle speed V**2** and the candidate value of the sound pressure L**2** adjusted by S**18** are determined as the vehicle speed V**2** and the sound pressure L**2**. A point represented by the vehicle speed V**2** and the sound pressure L**2** in the sound pressure control function **14***b* is referred to as a point P**2**.

[0041] In S**22**, the relation between the vehicle speed and the sound pressure of the approach notification sound between the point PI and the point P**2** is determined. Specifically, the relation between the vehicle speed and the sound pressure of the approach notification sound is determined so that the sound pressure of the approach notification sound gradually decreases as the vehicle speed increases from the vehicle speed V**1** to the vehicle speed V**2**. In the embodiment of FIG. **2**, as the vehicle speed increases from the vehicle speed V**1** to the vehicle speed V**2**, the sound pressure of the approach notification sound decreases linearly, but this is not necessarily the case.

[0042] As shown in FIG. **4**, in the related art, the approach notification sound is stopped when the vehicle speed of electrified vehicle EV becomes the vehicle speed Vp**1**.

[0043] On the other hand, in the present embodiment, even if the vehicle speed of electrified vehicle EV becomes the vehicle speed V**1**, the approach notification sound is not stopped, and as the vehicle speed increases from the vehicle speed V**1**, the sound pressure of the approach notification sound gradually decreases. As a result, at least the difference between the sound pressure of the approach notification sound immediately before the approach notification sound is stopped and the sound pressure of the background noise is reduced. Therefore, when the approach notification sound is stopped, a person in the vicinity of electrified vehicle EV or an uncomfortable feeling felt by the occupant is reduced.

[0044] In particular, in the present embodiment, control is performed so that the difference ΔL**2** between the sound pressure L**2** of the approach notification sound immediately before the approach notification sound is stopped (in the vehicle speed V**2**) and the sound pressure of the background noise in the vehicle speed V**2** is equal to or lower than the threshold sound pressure. Therefore, the uncomfortable feeling felt by the person or the occupant around electrified vehicle EV is more reliably reduced.

[0045] Although the embodiment of the vehicle approach notification device according to the present disclosure has been described above, the vehicle approach notification device according to the present disclosure is not limited to the above-described embodiment, and various modifications can be made without departing from the gist thereof.

Claims

1. A vehicle approach notification device comprising a sound pressure control unit that controls a sound pressure of an approach notification sound output from a sound generator provided in an electrified vehicle toward outside of the vehicle according to a vehicle speed of electrified vehicle, wherein the sound pressure control unit is configured to perform control such that the sound pressure of the approach notification sound gradually decreases as the vehicle speed of electrified vehicle increases when the vehicle speed of the electrified vehicle is higher than a threshold vehicle speed.

2. The vehicle approach notification device according to claim 1, wherein the sound pressure control unit is configured to stop output of the approach notification sound from the sound generator when a difference between the sound pressure of the approach notification sound and a sound pressure of background noise becomes equal to or less than a threshold sound pressure as a result of the sound pressure of the approach notification sound gradually decreasing as the vehicle speed of the electrified vehicle increases.