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STEERING LINKAGE ASSEMBLY, SEAL INTEGRITY DIAGNOSTIC SYSTEM AND TEST METHOD

Abstract

A steering linkage assembly includes a steering linkage that is operatively connectable to a pair of road wheels. The steering linkage assembly also includes a housing defining a sealed compartment containing at least a portion of the steering linkage. The steering linkage assembly further includes a first sealing boot operatively coupled to the steering linkage and located proximate a first end of the housing. The steering linkage assembly yet further includes a second sealing boot operatively coupled to the steering linkage and located proximate a second end of the housing, wherein the first sealing boot has at least one distinctive characteristic relative to the second sealing boot to define non-identical sealing boots.

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Background/Summary

FIELD OF THE INVENTION
[0001] This disclosure relates to a steering systems and, more particularly, to a steering linkage assembly, as well as a seal integrity diagnostic system and test method.
BACKGROUND
[0002] A vehicle, such as a car, truck, sport utility vehicle, crossover, mini-van, marine craft, aircraft, all-terrain vehicle, recreational vehicle, or other suitable vehicles, include various steering system schemes, for example, steer-by-wire (SbW) and driver interface steering. Often, the various steering schemes include an electric power steering (EPS) system including components such as a steering wheel, a column structure, a rack-pinion gear, an electric motor actuator, etc. The EPS helps the operator steer a vehicle by providing necessary assist torque and feedback.
[0003] Under-hood EPS applications are required to be sealed from the under-hood environment to ensure the integrity of the mechanical and electrical components within the unit. Standard processes to ensure that the unit is sealed from water intrusion involves leak testing the EPS unit on a steering assembly line. Once proven to be sealed, testing in the field is not routinely performed.
[0004] This method of the leak testing on the steering assembly line is typically sufficient to ensure the gear integrity as it leaves the leak test stand on the steering assembly line, but does nothing to ensure steering gear sealing integrity as the gear travels down the assembly line, to the vehicle assembly plant, as it is installed in the vehicle, or again during the life of the vehicle.
[0005] Accordingly, it would be well received in the industry to be able to verify the integrity of the EPS gear seals when it is in the field in order to mitigate any risk of failure modes, such as the potential loss of assist events due to water intrusion, prior to their occurrence.
SUMMARY
[0006] According to one aspect of the disclosure, a steering linkage assembly includes a steering linkage that is operatively connectable to a pair of road wheels. The steering linkage assembly also includes a housing defining a sealed compartment containing at least a portion of the steering linkage. The steering linkage assembly further includes a first sealing boot operatively coupled to the steering linkage and located proximate a first end of the housing. The steering linkage assembly yet further includes a second sealing boot operatively coupled to the steering linkage and located proximate a second end of the housing, wherein the first sealing boot has at least one distinctive characteristic relative to the second sealing boot to define non-identical sealing boots.
[0007] According to another aspect of the disclosure, a method to diagnose sealing integrity of a steering linkage assembly is provided. The method includes monitoring a pressure within a sealed compartment defined by a first sealing boot, a second sealing boot and a rack housing assembly, wherein the first sealing boot has at least one distinctive characteristic relative to the second sealing boot to define non-identical sealing boots. The method also includes moving a steering linkage at least partially disposed within the sealed compartment. The method further includes detecting a pressure change of the sealed compartment during movement of the steering linkage. The method yet further includes comparing the pressure change within the sealed compartment with a threshold pressure change to determine if the sealed compartment has a leak present.
[0008] These and other aspects of the present disclosure are disclosed in the following detailed description of the embodiments, the appended claims, and the accompanying figures.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0009] The disclosure is best understood from the following detailed description when read in

conjunction with the accompanying drawings. It is emphasized that, according to common practice, the various features of the drawings are not to-scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity.

[0010] FIG. **1** schematically illustrates a steering system having a steering gear;

[0011] FIG. **2** is a perspective view of a steering rack assembly;

[0012] FIG. **3** is a plot of volume vs. position for a steering gear system operating under a properly sealed condition; and

[0013] FIG. **4** is a plot of pressure vs. position for the steering gear system operating under a properly sealed condition.

DETAILED DESCRIPTION

[0014] The following discussion is directed to various embodiments of the disclosure. The embodiments disclosed herein should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to intimate that the scope of the disclosure, including the claims, is limited to that embodiment.

[0015] The present invention described herein may be incorporated into any suitable vehicle, such as a car, a truck, a sport utility vehicle, a mini-van, a crossover, any other passenger vehicle, any suitable commercial vehicle, or any other suitable vehicle. Moreover, principles of the present disclosure may apply to other vehicles, such as planes, boats, trains, drones, or other suitable vehicles. Moreover, the present invention may be incorporated into various steering system schemes and electric power steering (EPS) systems, including steer-by-wire systems.

[0016] As will be appreciated from the disclosure, a system and method is provided to detect failures of certain components due to fluid intrusion, such as water intrusion. In particular, the system and test method provides the ability to verify a steering gear sealing condition throughout the life of the vehicle. Although sealing protection of a steering gear is discussed in detail herein, it is to be appreciated that other components of a steering system may be monitored for sealing conditions with the embodiments disclosed herein.

[0017] Referring initially to FIG. **1**, a power steering system **20** is generally illustrated. The power steering system **20** may be configured as a driver interface steering system, an autonomous driving system, or a system that allows for both driver interface and autonomous or semi-autonomous steering. The steering system may include an input device **22**, such as a steering wheel or other HWAs, wherein a driver may mechanically provide a steering input by turning the steering wheel. An airbag device **24** may be located on or near the input device **22**. A steering column **26** extends along an axis from the input device **22** to an output assembly **28**. The steering column **26** may include at least two axially adjustable parts, for example, a first portion **30** and a second portion **32** that are axially adjustable with respect to one another. The output assembly **28** may include a pinion shaft assembly, an I-shaft, a cardan joint, steer-by-wire components or any other features conventionally located opposite the input device **22**. In other words, the steering column **26** may include a mechanical connection to the steering linkage (also referred to as a rack) or may be a steer-by-wire system that does not require a continuous mechanical connection. The output assembly **28** may connect to a power-assist assembly **34** via a connection **36**. The connection **36** may be one of a steering gear input shaft, a continuation of the pinion shaft assembly, or wired or wireless digital communication protocols.

[0018] The power-assist assembly **34** may operably connect to a steering linkage **40** via a steering gear assembly **38**. In operation, actuation of the driver input **22** causes a responsive movement of the power-assist assembly **34** and causes the steering linkage **40** to steer an associated vehicle via road wheels **42**, to which the steering linkage is operatively connected to. The power-assist assembly **34** may be part of a single pinion electronically assisted power steering (SPEPS) system, a dual pinion electronically assisted power steering (DPEPS) system, a column electrical power

steering (CEPS) system, or a recirculation ball-type rack electrical power steering (REPS) system.
[0019] Referring now to FIG. **2**, a portion of the steering column **26** passes under the hood of the vehicle, such that it is proximate the engine and fluid containing components. The disclosed system and testing method utilize a pressure sensor to sense the internal pressure of a sealed compartment that the steering linkage **40** is located within. In particular, a rack housing assembly **50** and a pair of seal boots **52** contain and seal the steering linkage **40** therein. More or fewer sealing components may be present in some embodiments, but the overall sealed compartment may be referred to herein as simply the sealed compartment.
[0020] The system and method disclosed herein monitor the internal pressure within the sealed compartment with a pressure sensor **60**. It has been observed that a volume change occurring within the seal boots **52** during translation of the steering linkage **40** during steering events is imbalanced between an expanding and contracting boot. Therefore, as the steering linkage **40** is steered to the left or right, an internal pressure change within the overall sealed compartment occurs due to the changing volume of the two boots. This pressure change may vary depending on the particular application. This pressure change is not observable if a significant leak is present in either of the boots **52** or other sealing members which define the sealed compartment. Accordingly, the system and testing method disclosed herein monitors for a given level of pressure change during a steering cycle in order to verify that a significant leak is not present.
[0021] As disclosed above, the pressure sensor **60** is positioned to monitor the pressure within the sealed compartment to determine whether a leak is present in the sealed compartment. The pressure sensor **60** may be any type of sensor suitable for monitoring the pressure ranges found within the sealed compartment and for the overall packaging constraints. The pressure sensor **60** may be positioned in numerous contemplated locations associated with the sealed compartment. For example, the pressure sensor **60** may be located within a first sealing boot **53** of the sealing boots **52** or within a second sealing boot **55** of the sealing boots **52**. By way of other non-limiting example, the pressure sensor **60** may be located within the rack housing assembly **50** proximate a gear assembly **62** powered by a motor or proximate a circuit card assembly **64**. Alternative locations associated with the sealed compartment are also contemplated. Regardless of the precise location of the pressure sensor **60**, the pressure sensor **60** is in operative communication (wired or wireless) with a processor and controller **100** that is able to convert the signal generated by the pressure sensor **60** into data that can be analyzed to assess whether the detected internal pressure of the sealed compartment is indicative of a leak.
[0022] The controller **100** compares the detected pressure change over a range of travel to a predetermined threshold pressure change. If a detected pressure change is lower than the threshold pressure change, the condition is indicative of a leak condition of the sealed compartment. In this event, the controller **100** issues a diagnostic warning if the leak condition is detected. The warning may be in the form of an alert to a vehicle operator or may be provided with special diagnostic tools used by maintenance personnel.
[0023] In another embodiment, the system and method analyze for a leak using the same inputs, but the steering maneuver (e.g., left turn or right turn) that results in the pressure change is held in that position to monitor pressure drop, which may allow for detection of a more refined leak rate. In such an embodiment, the pressure sensor **60** is in operative communication with the controller **100** and the controller **100** issues a diagnostic warning if the pressure drop exceeds a threshold pressure drop.
[0024] The above-described volumetric—and therefore pressure change—observed during movement of the steering linkage **40**, as well as the sealing boots, **53**, **55** is magnified when the first sealing boot **53** and the second sealing boot **55** are non-identical. The term “non-identical”, when referencing the sealing boots **53**, **55**, as used herein, refers to any difference in diameter, length, corrugation geometry, overall geometry, overall surface area, stiffness, and/or any other material property.

[0025] The detectable internal pressure change within the rack housing assembly **50** is generated by the sealing boots **53**, **55**, particularly by the non-identical structure of the boots. This is due to the volume change of the sealing boots **53**, **55** generated during collapsing and expanding of the sealing boots **53**, **55** during translation of the steering linkage **40**.
[0026] FIG. **3** illustrates the volume changes exhibited by each sealing boot **53**, **55** under an unleaked condition (i.e., properly sealed) of the sealing boots **53**, **55**. In particular, FIG. **3** is a plot of sealing boot volume vs. steering linkage position when the sealing boots **53**, **55** are operating under a properly sealed condition. The horizontal axis represents travel positions of a point on the steering linkage **40**. The steering linkage **40** is moved away from an "on center" position (referenced with 0 on horizontal axis) toward a right or left hand turn position.
[0027] The plot line referenced with numeral **200** represents the volume of the first sealing boot **53**, the plot line referenced with numeral **202** represents the volume of the second sealing boot **55**, and the plot line referenced with numeral **204** represents the summation of the volumes of the first sealing boot **53** and the second sealing boot **55**. These plot lines evidence volume changes of the first sealing boot **53**, the second sealing boot **55** and the combined volume change over the full range of travel of the steering linkage **40**.
[0028] FIG. **4** illustrates the pressure changes exhibited within the rack housing assembly **50** under an unleaked condition (i.e., properly sealed) of the sealing boots **53**, **55**—and the housing overall. In particular, FIG. **4** is a plot of pressure within the rack housing assembly vs. steering linkage position when the sealing boots **53**, **55** are operating under a properly sealed condition. The horizontal axis represents travel positions of a point on the steering linkage **40**. The steering linkage **40** is moved away from an "on center" position (referenced with 0 on horizontal axis) toward a right or left hand turn position.
[0029] The plot line referenced with numeral **300** represents the predicted overall system pressure (i.e., pressure within the rack housing assembly **50**) of an assembly utilizing two substantially identical sealing boots, as done in the prior art. The plot line referenced with numeral **302** represents data obtained during testing of an assembly utilizing two substantially identical sealing boots. As shown, while the magnitudes of plots **300** and **302** are offset, the behavior of the system pressure plots are generally similar and symmetric about the "on center" position.
[0030] The plot line referenced with numeral **304** represents the predicted overall system pressure of the embodiments disclosed herein, which includes two non-identical sealing boots (e.g., sealing boots **53**, **55**). The general shape and characteristics of pressure plot line **304** is starkly different than the generally symmetric shape of plot lines **300**, **302**. This distinctive pressure profile over the range of steering linkage **40** travel provides more certainty with diagnostic results related to sealing integrity of the sealing boots **53**, **55** and overall rack housing assembly **50**. In contrast, no significant pressure change is observed over a full steering travel range in situations where a leak is present.
[0031] The embodiments described herein may be used with a single pressure sensor in some embodiments. However, it is to be understood that more than one may be utilized for redundancy purposes. Nevertheless, the pressure sensor and monitoring during typical usage of the vehicle is less complex than prior leak diagnosing efforts that require several components and specific test routines.
[0032] Although FIG. **2** illustrates monitoring pressure of a sealed compartment with a pair of sealing boots, it is to be appreciated that pressure monitoring of a single sealing boot may be performed in some systems. Such an embodiment may be referred to as a "single wheel actuator system." In such a system, the monitored pressure change disclosed herein within the sealed compartment would fluctuate as the single boot is translated. It is to be understood that single boot embodiments are within the scope of the disclosed embodiments, as are overall sealed compartments with more sealing boots or other components.
[0033] While the invention has been described in detail in connection with only a limited number

of embodiments, it is to be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Moreover, any feature, element, component or advantage of any one embodiment can be used on any of the other embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description

Claims

1. A steering linkage assembly comprising: a steering linkage that is operatively connectable to a pair of road wheels; a housing defining a sealed compartment containing at least a portion of the steering linkage; a first sealing boot operatively coupled to the steering linkage and located proximate a first end of the housing; a second sealing boot operatively coupled to the steering linkage and located proximate a second end of the housing, wherein the first sealing boot has at least one distinctive characteristic relative to the second sealing boot to define non-identical sealing boots; and a pressure sensor positioned to detect an internal pressure within the sealed compartment over a range of travel of the steering linkage, wherein a pressure change lower than a pressure change threshold indicates a leak condition of the sealed compartment, wherein the internal pressure over a range of travel of the steering linkage is not symmetric about a center position based on the at least one distinctive characteristic of the first sealing boot relative to the second sealing boot.
2. (canceled)
3. The steering linkage assembly of claim 1, wherein the pressure sensor is at least partially disposed within the first boot.
4. The steering linkage assembly of claim 1, wherein the pressure sensor is at least partially disposed within the second boot.
5. The steering linkage assembly of claim 1, wherein the pressure sensor is at least partially disposed within the housing.
6. The steering linkage assembly of claim 1, further comprising an additional pressure sensor positioned to detect an internal pressure within the sealed compartment over a range of travel of the steering linkage.
7. The steering linkage assembly of claim 6, wherein the pressure sensor and the additional pressure sensor are in operative communication with a controller.
8. The steering seal diagnostic system of claim 1, wherein the pressure sensor is in operative communication with a controller.
9. The steering linkage assembly of claim 8, wherein the controller issues a diagnostic warning if the leak condition is detected.
10. The steering linkage assembly of claim 1, wherein the at least one distinctive characteristic is a sealing boot length.
11. The steering linkage assembly of claim 1, wherein the at least one distinctive characteristic is a sealing boot diameter.
12. The steering linkage assembly of claim 1, wherein the at least one distinctive characteristic is a sealing boot corrugation geometry, overall geometry, overall surface area, stiffness, and/or any other material property.
13. The steering linkage assembly of claim 1, wherein the at least one distinctive characteristic is a sealing boot material property.
14. The steering linkage assembly of claim 13, wherein the at least one distinctive characteristic is

a sealing boot stiffness.

15-19. (canceled)