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(54) ALTITUDE-DEPENDENT COMPRESSOR CONTROL

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(57) **ABSTRACT**

A method for controlling an electrically driven compressor, which can be switched on and off as a function of demand, of a pneumatic suspension system, wherein the temperature of the compressor is calculated according to a temperature model inside a control device, and the compressor is switched on or off as a function of the calculated temperature, wherein, for the calculation of the temperature of the compressor according to the temperature model, the control device takes into account the air pressure surrounding the vehicle as an input variable, and the parameters of the temperature model are adapted as a function of this air pressure.

ALTITUDE-DEPENDENT COMPRESSOR CONTROL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is the U.S. National Phase Application of PCT/EP2011/057011, filed May 3, 2011, which claims priority to German Patent Application No. 10 2010 017 654.0, filed Jun. 30, 2010, the contents of such applications being incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The invention relates to a method for controlling an electrically driven compressor, which can be switched on and off as a function of demand, of a pneumatic suspension system, wherein in the method the temperature of the compressor or the temperature of the air compressed in the compressor is calculated according to a temperature model inside a control device, which temperature model takes into account, as input variables, inter alia the electrical voltage of the compressor, the surrounding temperature and the pressure ratios in the pneumatic suspension system, after which the compressor is switched on or off as a function of the calculated temperature.

BACKGROUND OF THE INVENTION

[0003] In order to supply pneumatic springs in vehicles, hitherto for the most part electrically driven compressors have been used in which the structure and selection of material during manufacture are optimized by using service life calculations and/or by assuming load spectra in order to make commercially available compressors which are as economical as possible and nevertheless sufficiently durable. For this purpose, it is then however also to a certain extent necessary to provide complex methods for controlling the compressors, which methods can be used to switch the compressor drive on and off as a function of the necessary system pressure, of the temperature, and/or as a function of the running time, in order thereby to avoid exceeding predetermined load spectra and temperature spectra.

[0004] EP 1 644 640 B1, which is incorporated by reference, discloses a method for controlling the operation of the compressor in which the compressor is switched off by a control device to avoid thermal damage if a temperature estimated value which is calculated by the control device exceeds an upper threshold value. In the known method, the control device uses the temperature estimated value as a state of the variable to calculate a cooling function which represents the time profile of the cooling of the compressor.

[0005] DE 196 21 946 C2, which is incorporated by reference, discloses a method in which an estimated value is continuously predefined for the current operating temperature of the compressor. When the compressor is switched on, the last estimated value is respectively increased by a predefined small temperature difference after a predefined time period, and when the compressor is switched off the last estimated value of the temperature is respectively lowered by a predefined small temperature difference after a predefined time period. If the estimated value which is calculated in this way for the switched-on compressor exceeds and upper threshold value, the compressor is switched off. After the switch-off, the compressor can be switched on again if the estimated value exceeds a lower threshold value. The compressor is therefore to be reliably protected against excessive generation of heat in the switched-on state.

[0006] DE 198 13 672 C1, which is incorporated by reference, discloses a pneumatic suspension system for a vehicle, in which system both the pressure in a pressure accumulator is measured with a sensor and processed from a signal value for the control, and the ambient pressure, i.e. the air pressure in the surroundings of the vehicle, is measured and is processed from a further signal value for the control.

[0007] An electrically driven, single-stage compressor which is present in the pneumatic suspension system fills the pressure accumulator up to a pressure which is usually between a lower and upper limiting pressure. The volume flow fed by the electrically driven compressor depends, of course, on the respective ambient pressure and on the counterpressure in the pressure accumulator.

[0008] The teaching of DE 198 13 672 C1 comprises forming the controller in such a way that the upper and/or the lower limiting pressure in the pressure accumulator at which the compressor automatically switches on and/or switches off are defined as a function of the ambient pressure. Since the maximum air pressure which can be achieved by means of the compressor in order to supercharge the pressure accumulator is perceptibly lower at high altitudes, that is to say for example, when travelling in mountains, than at sea level, the usually permanently set upper limiting pressure of, for example, 18 bar at high altitudes would never be reached, and the compressor would not be switched off again, without the solution in DE 198 13 672 C1. This can lead to overheating and to destruction of the compressor.

[0009] DE 10 2006 039 538 A1, which is incorporated by reference, relates to a pneumatic suspension system of a motor vehicle and to a method for controlling an associated compressor which can be switched on and off as a function of demand and in which the temperature of the air which is compressed in the compressor is calculated with a temperature model during the running times of the compressor. In this context, a different temperature model is used as a basis for the first run of the compressor than for the subsequent runs of the compressor, which causes the first running time of the compressor to be prolonged compared to the subsequent running times and therefore an optimized running time behavior.

SUMMARY OF THE INVENTION

[0010] An aspect of the invention provides a method for controlling a compressor, which can be switched on and off as a function of demand, of a pneumatic suspension system of a motor vehicle in which, on the one hand, all the components of the compressor are well protected against damage due to excessive generation of heat even when the vehicle is used at very different geodetic altitudes and, on the other hand, a sufficient running time of the compressor is reached to be able to reliably carry out filling/refilling processes.

[0011] This aspect is achieved by means of a pneumatic suspension system for a motor vehicle having a control device for carrying out a method for controlling an electrically driven compressor, which can be switched on and off as a function of demand, of a pneumatic suspension system, wherein the temperature of the compressor is calculated according to a temperature model inside a control device, and the compressor is switched on or off as a function of the calculated temperature, wherein for the calculation of the temperature of the compressor according to the temperature model, the control device takes into account the air pressure surrounding the vehicle as an input variable, wherein the parameters of the temperature model are adapted as a function of this air pressure. Further advantageous embodiments are disclosed in the dependent claims.

DETAILED DESCRIPTION OF THE INVENTION

[0012] In this context, the control device which is necessary for the method is configured in its algorithms in such a way that, for the calculation of the temperature of the compressor according to the temperature model, the control device takes into account the air pressure surrounding the vehicle (i.e. the ambient pressure) as an input variable, wherein the parameters of the temperature model are adapted as a function of this air pressure. Even if delivery capacity drops markedly at high altitudes, i.e. far above sea level, compared to the delivery capacity at sea level due to the reduced air pressure, the formation of the method according to the invention can at least partially correct this effect through an increased compressor running time. Through the counterpressure/filling pressure in the compressor cylinder which is correspondingly lower at high altitudes, the compressor in fact becomes less warm. At high altitudes, the low ambient pressure (admission pressure) of the compressor is responsible for the fact that the volume flow is smaller and also the heating of the compressor is less. In contrast, switching off according to the "normal" temperature model without taking into account the ambient pressure as an input variable and correspondingly adapting the parameters of the temperature model would take place too early and would therefore not make available the necessary air quantities in the system. The fact that the "saturation pressure" of the compressor is lower at high altitudes than at sea level is unaffected by this. The term "saturation pressure" is understood in this case to mean the ambient pressure at which the ratio between the admission pressure (ambient pressure) and the counterpressure in the compressor cylinder is embodied in such a way that delivery is no longer possible.

[0013] Basically, during the development of pneumatic suspension systems for off-road vehicles which can also be used in mountainous terrain, it has been found that at an altitude of 2800 m above sea level the "normal" temperature model supplies values for the compressor temperature which are too poorly predicted. However, since the vehicle must be able to react sufficiently quickly to a change of load through adaptation of the system air quantities even at altitudes far above sea level, only the inventive embodiment of the method is capable of supplying good predictions for the compressor temperature.

[0014] An advantageous development consists in the fact that the control device takes into account the air pressure surrounding the vehicle as an input variable only during filling processes of the pneumatic suspension system from the atmosphere. As a result, relatively long running times of the compressor are also switched only in these cases and at high altitudes by means of more precise temperature predictions. This leads, of course, to a saving in energy. In the previous types of closed pneumatic suspension systems (GLV) with correspondingly configured pressure accumulators, the requirement for the ambient pressure to be taken into account was and is, of course, hardly necessary since here a change in the system air quantities is necessary only in the cases of leakage. In vehicles with a closed pneumatic suspension system, a change of load alone does not require altitude-dependent adaptation of the air quantities in the system for reasons associated with the system. However, it is all the more important for the ambient pressure to be taken into account in vehicles with an open pneumatic suspension system (OLV), that is to say vehicles which have to compensate air losses from the surroundings.

[0015] A further advantageous embodiment consists in the fact that the adaptation of the parameters of the temperature model takes place incrementally as a function of the ambient air pressure. This means that it is only approximately determined at what altitude the vehicle is located. This could take place, for example, in three stages, specifically:

[0016] a) the vehicle is at sea level,

[0017] b) the vehicle is at 1000 m-2000 m above sea level, and

[0018] c) the vehicle is higher than 2000 m above sea level.

[0019] Such stages are already sufficient for good adaptation of the temperature model. Trials show that by means of this procedure it is possible to achieve a representation of the calculated model temperature With the measured temperature which is close to real conditions.

[0020] A further advantageous embodiment consists in the fact that the air pressure surrounding the vehicle is determined by the control device of an air conditioning system which is present in the vehicle and is predefined as an input variable of the control device. In this context, in a particularly elegant way, it is possible to access already existing data. Systems are presently under development in which the ambient pressure is determined by the software of the air conditioning controller and is made available to the control device of the pneumatic suspension system via the CAN-BUS.

[0021] A further advantageous embodiment consists in the fact that the air pressure surrounding the vehicle is determined by calculation from the absolute altitude of the vehicle above sea level which is predefined by means of a position-determining system (GPS, Global Positioning System), and said air pressure is predefined as an input variable of the control device. The calculation can take place, for example, in the GPS system or in the control device of the pneumatic suspension system. By using a GPS receiver, it is possible to infer an ambient pressure by detecting the absolute altitude by means of the isobar pressure formula. Even if at present there are still too few vehicles equipped with a GPS receiver, it is already readily possible to transmit this data to the control device of the pneumatic suspension system.

[0022] A further embodiment which is advantageous because it is simple and can be easily implemented with known sensors comprises the air pressure surrounding the vehicle being determined by a sensor provided in the pneumatic suspension system and is predefined as an input variable of the control device.

[0023] The method can advantageously be used, as already stated, in a pneumatic suspension system for a motor vehicle.

1-7. (canceled)

8. A method for controlling an electrically driven compressor, which can be switched on and off as a function of demand, of a pneumatic suspension system, wherein the temperature of the compressor is calculated according to a temperature model inside a control device, and the compressor is switched on or off as a function of the calculated temperature, wherein

for the calculation of the temperature of the compressor according to the temperature model, the control device takes into account the air pressure surrounding the vehicle as an input variable, wherein the parameters of the temperature model are adapted as a function of this air pressure.

9. The method as claimed in claim **8**, wherein the control device takes into account the air pressure surrounding the vehicle as an input variable during filling processes of the pneumatic suspension system from the atmosphere.

10. The method as claimed in claim **8**, wherein the adaptation of the parameters of the temperature model takes place incrementally as a function of the surrounding air pressure.

11. The method as claimed in claim **8**, wherein the air pressure surrounding the vehicle is determined by the control device of an air conditioning system which is present in the vehicle and is predefined as an input variable of the control device.

12. The method as claimed claim **8**, wherein the air pressure surrounding the vehicle is determined by calculation from the absolute altitude of the vehicle above sea level, which is predefined by a position-determining system, and said air pressure is defined as an input variable of the control device.

13. The method as claimed in claim **8**, wherein the air pressure surrounding the vehicle is determined by a sensor provided in the pneumatic suspension system and is predefined as an input variable of the control device.

14. A pneumatic suspension system for a motor vehicle having a control device for carrying out a method for controlling an electrically driven compressor, which can be switched on and off as a function of demand, of a pneumatic suspension system, wherein the temperature of the compressor is calculated according to a temperature model inside a control device, and the compressor is switched on or off as a function of the calculated temperature, wherein for the calculation of the temperature of the compressor according to the temperature model, the control device takes into account the air pressure surrounding the vehicle as an input variable, wherein the parameters of the temperature model are adapted as a function of this air pressure.

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