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(54) **DEVICE FOR MONITORING AN EXHAUST GAS CATALYTIC CONVERTER FOR AN INTERNAL COMBUSTION ENGINE**

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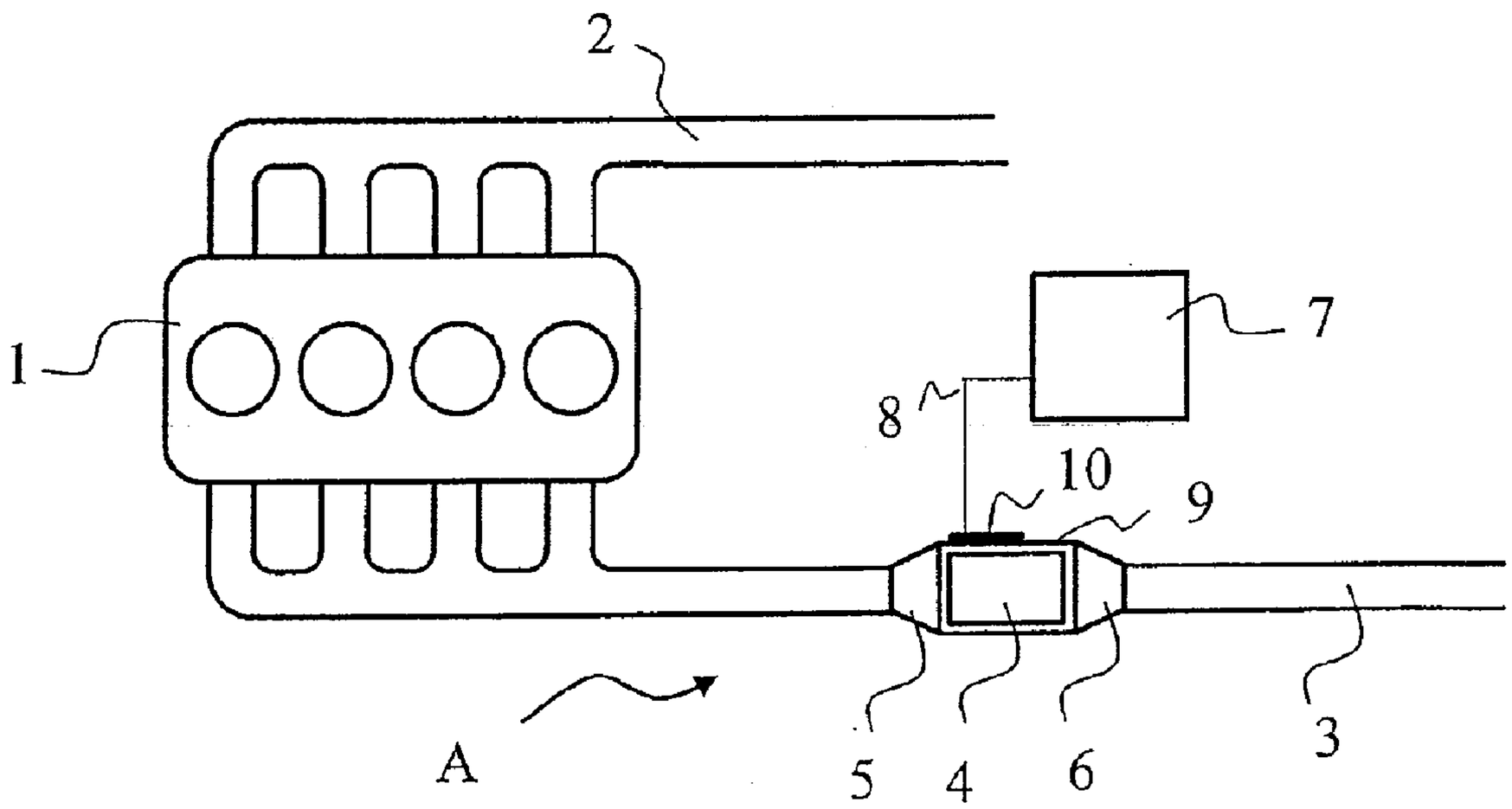
(57) **ABSTRACT**

A device for monitoring an exhaust gas catalytic converter in the exhaust system of an internal combustion engine, includes a measuring apparatus that is arranged in the exhaust system in such a way that, in the greatest part of the operating range of the internal combustion engine, it assumes a temperature that is correlated with a temperature of the exhaust gas catalytic converter. The measuring apparatus has a temperature-sensitive component with a temperature-dependent characteristic component parameter that changes either abruptly at a predetermined transition temperature or temperature range, or continuously in a predetermined way as a function of the temperature. A control and evaluation unit connected to the measuring arrangement detects the characteristic component parameter and/or a change in the latter, and correlates it with an aging state of the exhaust gas catalytic converter.



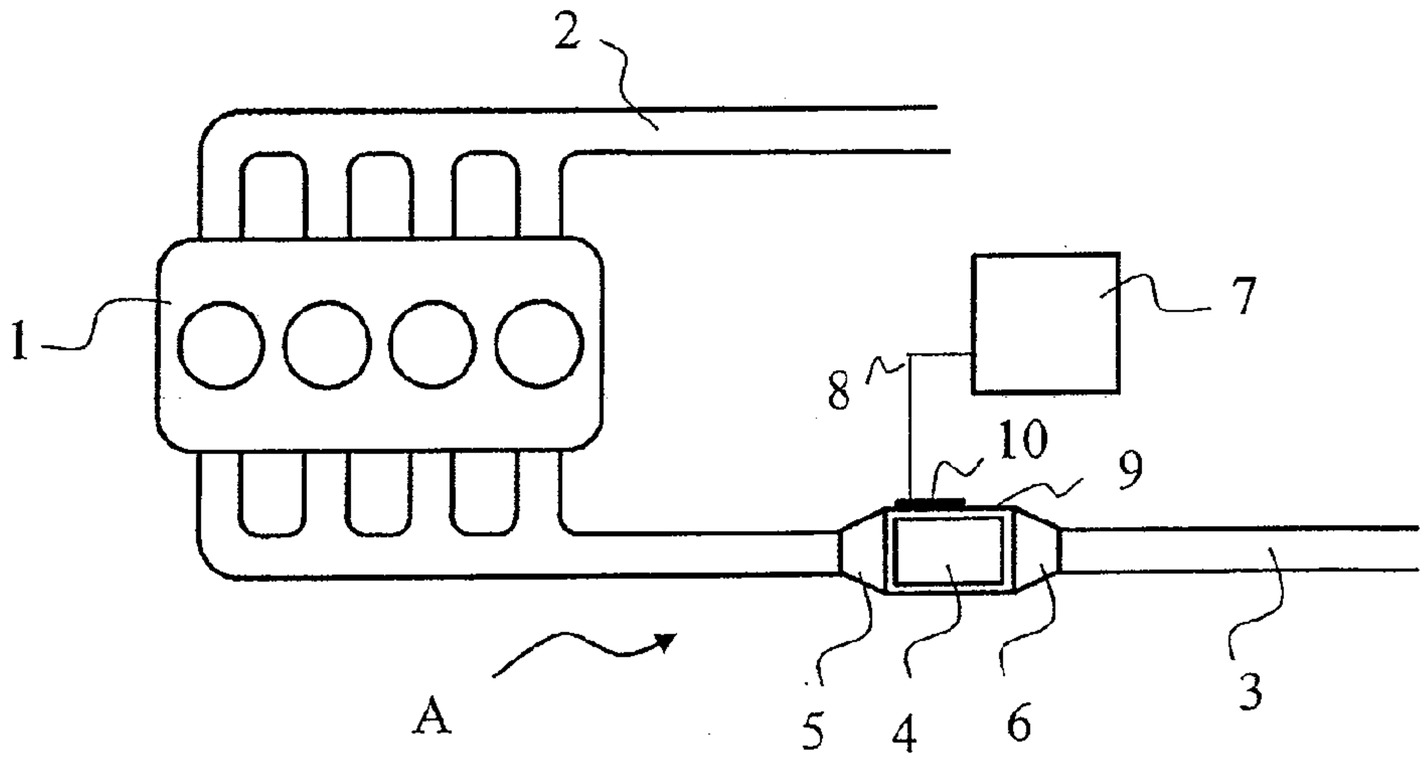


Fig. 1

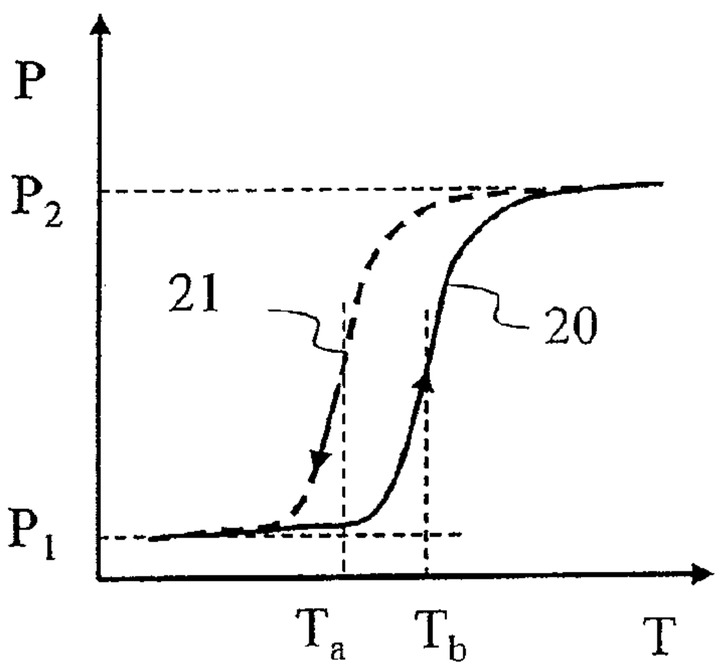


Fig. 2

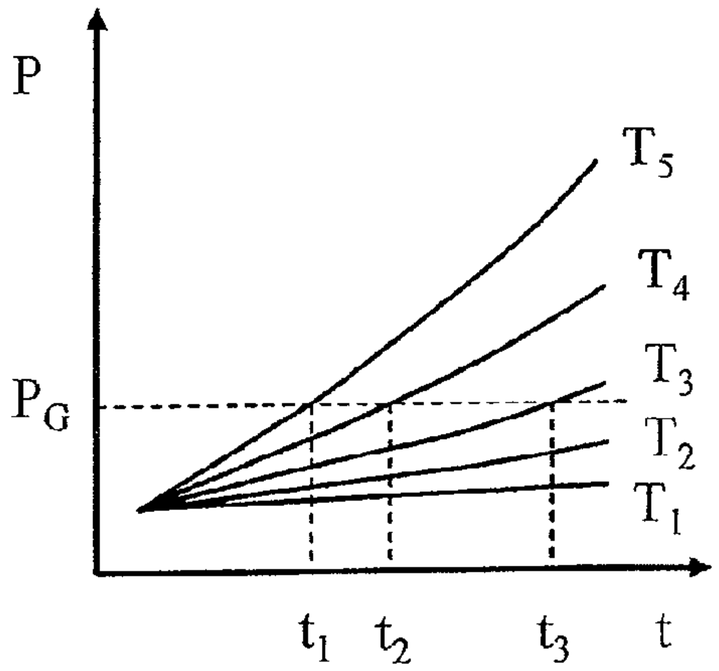


Fig. 3

DEVICE FOR MONITORING AN EXHAUST GAS CATALYTIC CONVERTER FOR AN INTERNAL COMBUSTION ENGINE

[0001] This application is a national stage of PCT Application No. PCT/EP2007/002989, filed Apr. 3, 2007, which claims priority under 35 U.S.C. §119 to German Patent Application No. 10 2006 016 906.9, filed Apr. 11, 2006, the entire disclosure of which is herein expressly incorporated by reference.

BACKGROUND AND SUMMARY OF THE INVENTION

[0002] The invention relates to a device for monitoring an exhaust gas catalytic converter in the exhaust system of an internal combustion engine. In particular, the invention relates to such a monitoring device having a measuring arrangement which is disposed in the exhaust system in such a way that, at least in the predominant part of the operating range of the internal combustion engine, it assumes a temperature correlated with a temperature of the exhaust gas catalytic converter.

[0003] Exhaust gas catalytic converters may partially or completely lose their effectiveness when they are exposed to high temperatures. In this context, temperature loads have a particularly pronounced effect on the effectiveness of a catalytic converter at low temperatures, for example during a cold start of the associated internal combustion engine. It is known, in this respect, to monitor the temperature of the exhaust gas catalytic converter in order to detect inadmissible peak temperatures, and to evaluate catalytic converter damage caused as a result. In addition, devices are known which can detect a reduction in the action of a exhaust gas catalytic converter directly.

[0004] In German patent document DE 43 08 661 A1 the temperature of the catalytic coating and/or of the structure of an exhaust gas catalytic converter and also the temperature of the exhaust gas, is determined upstream of the exhaust gas catalytic converter. Based on the time derivatives of the temperatures and their difference, a conclusion can be drawn as to the effectiveness of the exhaust gas catalytic converter.

[0005] International patent document WO 96/01364 discloses a device having a catalytically coated thermal conductivity sensor, which makes it possible to establish whether heat-delivering catalytic reactions are taking place to the intended extent. For example, an age-induced diminution in the catalytic converter activity can be determined in this manner.

[0006] It is known from German patent document DE 198 05 928 A1 to determine a physical property of the coating of a gas-storing catalytic converter and to determine the effectiveness of the catalytic converter on the basis of this property.

[0007] The devices described above are aimed at detecting the catalytic converter action which may be impaired, for example, by inadmissibly high temperatures. However, the catalytic converter action often cannot be determined with the desired reliability in this way. Moreover, the corresponding monitoring methods and devices for catalytic converter monitoring are often complicated.

[0008] One object of the invention, therefore, is to provide a device which reliably monitors an exhaust gas catalytic converter in as simple a way as possible.

[0009] This and other objects and advantages are achieved by the measuring apparatus according to the invention, which has a temperature-sensitive component with a characteristic parameter that is temperature-dependent and changes abruptly at a predetermined transition temperature, or in a predetermined transition temperature range, or changes continuously in a predetermined manner, as a function of the temperature. A control and evaluation unit connected to the measuring arrangement can detect the characteristic component parameter and/or its change.

[0010] A temperature-sensitive component having a characteristic component parameter which changes continuously in a predetermined manner as a function of the temperature, is expediently designed such that the change occurring over time is correlated with a parallel-running degradation of the exhaust gas catalytic converter. By means of such a component having a characteristic component parameter that changes abruptly as a function of temperature, it is possible to detect reliably whether the exhaust gas catalytic converter has overshot a temperature critical for its effectiveness, since a correspondingly high signal deviation occurs which can be detected reliably. For this purpose, taking into account the place of installation of the measuring arrangement, the temperature-sensitive component is designed such that the transition temperature or the transition temperature range of the characteristic component parameter is correlated with this critical temperature.

[0011] Thus, by means of the device according to the invention, essentially the cause of thermal damage is determined, more reliably and in a less complicated manner.

[0012] The changing characteristic component parameter may be a temperature-dependent mechanical, electrical or other specific material property of the component. The temperature-sensitive component is therefore preferably mechanical or electrical, and may be designed such that the material property changes reversibly under the intended thermal conditions. A more or less pronounced hysteresis with respect to the temperature dependence is expedient in this case.

[0013] Examples of temperature-sensitive components with mechanical properties changing abruptly as a function of temperature are bimetallic switches or what are known as "shape memory components". Examples of temperature-sensitive components with electrical properties changing abruptly as a function of temperature are cold conductors or hot conductors. In order to obtain a good correlation between the component temperature and catalytic converter temperature, it is expedient to arrange the measuring apparatus in the immediate vicinity of the exhaust gas catalytic converter in the exhaust system, preferably such that it assumes approximately the same temperature as the exhaust gas catalytic converter itself when the internal combustion engine is in operation.

[0014] In a refinement of the invention, the measuring apparatus is fixedly connected to the exhaust gas catalytic converter or to a housing which contains the exhaust gas catalytic converter. A fixed connection is understood here, as is generally conventional in connection technology, to mean a connection, upon the release of which the separated individual parts and/or the connection means are destroyed or damaged. In this case, connection parts of the housing, such as inflow or outflow funnels or connection pieces, are considered to belong to the housing.

[0015] As a result of this embodiment, the measuring apparatus cannot be separated non-destructively from the exhaust gas catalytic converter or from the housing of the exhaust gas catalytic converter. The housing and measuring apparatus or the catalytic converter and measuring apparatus thus form a unit which cannot be separated non-destructively. Misinterpretations of the information delivered by the measuring arrangement as a result of an intended or unintended separation of the measuring arrangement from the exhaust gas catalytic converter are thus prevented. This achieves particularly high reliability in the assignment of data which are provided by the measuring arrangement.

[0016] In a further embodiment of the invention, the change in the characteristic component parameter is irreversible. Once it has occurred, therefore, the change can be detected unequivocally, so that interpretation difficulties are avoided.

[0017] In a further refinement of the invention, the change in the characteristic component parameter is based on a structural transformation of a material constituent of the temperature-sensitive component. This is preferably a change in the structure of a material constituent of the component, for example in the form of recrystallization processes, sintering, melting, material agglomeration, island formation or the like. This type of transformation mostly takes place at a predetermined unambiguous transformation temperature or in the predetermined material-specific temperature range or as a function of the temperature within a known time profile. A change, once it has occurred, is therefore linked unambiguously to the corresponding temperature or to a duration of action or to a temperature/timing integral. Temperature action of predetermined intensity can therefore be established unambiguously.

[0018] In yet a further embodiment of the invention, the temperature-sensitive component of the measuring apparatus is a passive electrical structural element, such as an electrical resistor. However, the temperature-sensitive component may also be a capacitively or inductively active electrical component. Preferably, the temperature-sensitive component comprises a material having a function-determining material property, such as specific resistance, dielectric constant, permeability, curie temperature or the like, which changes abruptly at a predetermined transition temperature or in a predetermined transition temperature range.

[0019] In a further refinement of the invention, the temperature-sensitive component is produced by thick-film technology. This embodiment allows a substantial miniaturization, along with a flat set-up, resulting in simple and flexible installation possibilities and in good heat transmission.

[0020] In still a further refinement of the invention, the measuring apparatus includes a plurality of temperature-sensitive components that differ from one another in terms of the transition temperature (or range) of their characteristic component parameter, or individual temperature-sensitive components having characteristic component parameters that change in time in a different way as a function of the temperature. In this manner, the different temperatures of action and/or durations of action on the measuring arrangement or on the exhaust gas catalytic converter can be differentiated. Their action on an effectiveness parameter of the exhaust gas catalytic converter can thus likewise be evaluated in a differentiated way.

[0021] In another embodiment of the invention, the temperature-sensitive component is designed in such a way that the transition temperature or the transition temperature range of its characteristic component parameter is correlated with a permissible upper operating temperature of the exhaust gas catalytic converter, or the change in the characteristic component parameter which occurs in the course of time is correlated with a parallel-running aging of the exhaust gas catalytic converter. Thus, a particularly reliable catalytic converter diagnosis is possible. In particular, an overshooting of a predetermined upper limit temperature of the exhaust gas catalytic converter can be detected especially reliably. A warning message preferably occurs in this case. The critical data for the catalytic converter are preferably stored in preset characteristic curves or characteristic maps.

[0022] Furthermore, according to the invention, a device as described above is used to monitor an exhaust gas catalytic converter, designed as an oxidation catalytic converter, in the exhaust system of an internal combustion engine. More particularly, it is used to monitor an oxidation catalytic converter with a negligible capability for the storage of oxygen. It is especially advantageous to use the device according to the invention in an oxidation catalytic converter arranged near the engine. In this case, other diagnostic devices often encounter installation problems due to space limitations.

[0023] It is also highly advantageous to use the device according to the invention to monitor an oxidation catalytic converter with a low or absent oxygen possibility, since, in this case, monitoring of diagnostic methods based on oxygen storability is not possible. This advantage is beneficial particularly in connection with an oxidation catalytic converter of a diesel engine, for which the oxygen probes often used for diagnostic purposes in gasoline engines do not have sufficient sensitivity, because of the high oxygen excess in the exhaust gas.

[0024] Further features and advantages of the present invention arise from the following description of preferred exemplary embodiments. In this case, the features mentioned above and those yet to be explained below can be used not only in the feature combination specified in each case, but also in other combinations or alone, without departing from the scope of the present invention.

[0025] The invention is explained in more detail below by means of drawings and accompanying examples.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. **1** is a diagrammatic illustration of an advantageous embodiment of the invention in connection with an internal combustion engine having an exhaust system;

[0027] FIG. **2** is a diagrammatic illustration of the temperature dependence of a component parameter; and

[0028] FIG. **3** is a diagrammatic illustration of the time dependence of a component parameter in the case of different temperatures.

DETAILED DESCRIPTION OF THE INVENTION

[0029] FIG. **1** illustrates an internal combustion engine **1**, preferably a diesel engine, with an intake air line **2** with an exhaust system A. The exhaust system A comprises an exhaust gas line **3** in which a housing **9** encloses an exhaust gas catalytic converter **4**. The housing **9** is connected to the exhaust gas line **3** via an inflow funnel **5** and an outflow funnel **6**. Furthermore, a measuring apparatus **10**, is connected to a control and evaluation unit **7** via a signal line **8**. The measur-

ing apparatus **10** and the control and evaluation unit **7** connected to it, monitor the exhaust gas catalytic converter **4**, in the manner described.

[0030] The exhaust gas catalytic converter, preferably an oxidation catalytic converter, is arranged, preferably near the engine, in the exhaust gas line **3**. In particular, the exhaust gas catalytic converter is preferably an oxidation catalytic converter with a coating having low or negligible oxygen storability. A characteristic curve or characteristic map for the exhaust gas catalytic converter **4**, which is stored for example in the control and evaluation unit **7**, contains temperature values critical for the aging of the exhaust gas catalytic converter **4**. The exhaust gas catalytic converter **4** is monitored in terms of its temperature-induced damage or aging by comparing temperature values detected by the measuring apparatus **10** with the stored critical temperature values.

[0031] Depending on the size of the corresponding temperature value, different reactions may be provided by the control and evaluation unit **7**. For example, entries into a read-out fault store or warning messages may be provided. However, if critical temperature values occur, actions on the operation of the internal combustion engine **1** may be provided, such that the latter is operated to avoid high exhaust gas temperatures. If an upper peak temperature for the exhaust gas catalytic converter **4** is exceeded, a message relating to damage to the exhaust gas catalytic converter **4** is preferably output.

[0032] The measuring apparatus **10** is arranged in the exhaust system A in such a way that its temperature when the internal combustion engine is in operation is correlated in a known way with that of the exhaust gas catalytic converter **4**. This ensures that the information from the measuring apparatus **10** regarding the temperature of the exhaust gas catalytic converter **4** is realistic and reliable.

[0033] In the representative embodiment of FIG. **1**, the measuring apparatus **10** is fastened to the outer surface of the housing **9** in which the exhaust gas catalytic converter **4** is installed, making the invention especially assembly-friendly. However, the measuring apparatus **10** may also be mounted on the inner surface of the housing **9**, on the outside or inside of the inflow funnel **5** or outflow funnel **6** or on the outer wall of the exhaust gas catalytic converter **4**. The measuring apparatus **10** may, for example, be printed or glued directly on the outer surface of the exhaust gas catalytic converter **4**. This makes simple manufacture possible. There may, however, also be provision for integrating the measuring apparatus **10** into the exhaust gas catalytic converter **4**, for example into the duct structure of the latter. This allows an especially reliable detection of the catalytic converter temperature.

[0034] Preferably, the components of the measuring apparatus **10** are attached to a mechanical carrier, and the carrier, for example in the form of a flat ceramic substrate, is connected to the exhaust gas catalytic converter **4** or to the housing **9**. However, the components of the measuring apparatus **10** may also be applied directly to the exhaust gas catalytic converter **4** or to the housing **9**.

[0035] The mounting of the measuring apparatus **10** preferably takes place in such a way that good heat transmission from the exhaust gas catalytic converter **4** to the measuring apparatus **10** is obtained. Good heat transmission, at the same time with an unreleasable connection, may be achieved, for example, in a materially integral way by the adhesive bonding of a component or component carrier of the measuring apparatus **10** or by the soldering of the underside, provided with metallization, of a carrier substrate of the measuring apparatus **10** to the metallic housing **9** of the catalytic converter **4**. This ensures that the measuring apparatus **10** or the components of the measuring apparatus **10** cannot be removed nondestructively from the place of their mounting. This prevents a loss the correlation of the temperatures to which the measuring apparatus **10** and the exhaust gas catalytic converter **4** are exposed, due to intended or unintended mechanical actions. A specific measuring apparatus is thus assigned permanently to a specific example of a catalytic converter.

[0036] From experimentally obtained information, the temperature to which the measuring apparatus **10** is exposed can be correlated with the temperature of the exhaust gas catalytic converter **4** by the control and evaluation unit **7**. It is thus possible to correlate the temperature of the measuring arrangement with that of the exhaust gas catalytic converter **4**, even when a measuring apparatus **10** is not in direct heat transmission contact with the exhaust gas catalytic converter **4**.

[0037] For temperature monitoring and diagnosis of the exhaust gas catalytic converter **4**, the measuring apparatus **10** may have at least one temperature-sensitive component with a characteristic component parameter which changes abruptly as a function of temperature at a predetermined transition temperature or temperature range. FIG. **2** illustrates this situation by a diagrammatic characteristic curve graph for the temperature dependence of the characteristic component parameter P.

[0038] The temperature-sensitive component of the measuring apparatus **10** may be designed such that its characteristic parameter P increases abruptly from the value P_1 to the value P_2 according to the curve branch **20** at a temperature of about T_b. (The change may be reversible or irreversible.) Of course, instead of an abrupt increase in the characteristic component parameter P at the transition temperature T_b, an abrupt reduction is also possible in a similar way, in which case the component of the measuring apparatus **10** expediently has a transition temperature T_b that is correlated with a characteristic aging or damage temperature of the exhaust gas catalytic converter **4**.

[0039] As a result of the steep profile of the characteristic curve **20**, an overshooting of the critical transition temperature T_b can be detected with high reliability. It is, of course, advantageous if the surge occurring due to the values P_1 and P_2 is as high as possible. Although preferable, the change in the characteristic component parameter P does not necessarily have to have an especially steep profile. A less steep rise within a predetermined temperature range may likewise be quite sufficient. However, the change should be such that the gradient of the characteristic curve **20** is greater in the critical temperature range than in the following temperature ranges. In this case, too, a desired switching behavior of a component property characterized by the parameter P is afforded.

[0040] In the event of an abrupt reversible change in the component parameter P, it may be advantageous to provide the temperature-sensitive component with a hysteresis, as illustrated by the additional characteristic curve branch **21**. In this case, a changeover of the component property characterized by the parameter P takes place at different temperatures T_b, T_a, depending on the direction of the temperature change. Owing to this component property, undefined states at a respective transition temperature Tb, Ta can be avoided, and the interpretation of a useful signal obtained from the parameter P is correspondingly reliable.

[0041] For temperature monitoring and diagnosis of the exhaust gas catalytic converter **4**, the measuring apparatus **10** may also have at least one temperature-sensitive component with a characteristic component parameter that changes in a predetermined way over time, as a function of the temperature. For example, FIG. **3** illustrates a family of characteristic curves which show the time dependence of the characteristic component parameter P at various temperatures T_1 to T_5 ordered according to size. Expediently, the profiles of the characteristic curves assigned to the temperatures T_1 to T_5 are adapted to the aging behavior of the exhaust gas catalytic converter **4**. It is preferable if the changes in the characteristic component parameter which occur over time are irreversible, corresponding, in general, to irreversible catalytic converter aging, particularly when it is caused thermally.

[0042] Preferably, the component parameter P has a predetermined upper limit P_G which is correlated with an upper tolerance limit for an aging or degradation of the exhaust gas catalytic converter **4**. As is evident from the graph of FIG. **3**, the upper limit P_G reached at different times, depending on temperature. Thus, aging of the exhaust gas catalytic converter **4** which takes place at different rates at different temperatures can be diagnosed. For example, a no longer acceptable impairment of the catalytic converter behavior as a result of the short duration of action t_1 of the high temperature T_5 can be detected. However, a similarly pronounced impairment which has occurred as a result of the longer duration of action t_3 of the lower temperature T_3 can also be detected.

[0043] So that the effect of different temperatures on the catalytic converter can be detected in an even more differentiated way, the measuring apparatus **10** may have a plurality of temperature-sensitive components, each with a different behavior. For example, a plurality of temperature-sensitive components with different transition temperatures or transition temperature ranges may be provided. Additionally or alternatively, a plurality of temperature-sensitive components may also be provided, the characteristic component parameter of which changes in time in a different way as a function of the temperature.

[0044] It is particularly preferable if the component whose characteristic component parameter has the highest transition temperature or temperature range, is a continuously measuring temperature-sensitive component. It is advantageous, in this respect, for the component to be a resistance thermometer having a temperature-dependent electrical resistance that can be used for continuous temperature measurement at low temperatures, but abruptly changes (reversibly or irreversibly) at a predetermined transition temperature. Thus, in addition to reliable detection of the overshooting of the transition temperature, continuous temperature measurement is made possible.

[0045] The temperature-sensitive component is preferably produced as a passive electrical structural element by thick-film technology. It may be printed as a conductor track or conductor structure on a substrate by thick-film technology. The material for this purpose is selected so that, at a predetermined temperature or as a function of the temperature, it experiences, in a way predetermined in time, a transformation which, as explained above, is reflected in a change of a characteristic parameter. This is preferably the real and/or imaginary part of the complex impedance of the structural element.

[0046] If the temperature-sensitive component comprises a resistive structural element, it is preferable if its characteristic component parameter is represented by its electrical conductivity or resistance. In the case of a capacitive structural element, its material is preferably selected such that the dielectric constant (and therefore the capacitance and/or the loss angle) change as a function of temperature. The changes occurring as a function of temperature may be caused, for example, by melting, sintering, island formation, diffusion processes, material creep and/or crack formation of a material constituent of the temperature-sensitive component.

[0047] Instead of the characteristic parameters mentioned, however, other physical, in particular electrical characteristic variable, such as, for example, inductance, permeability, magnetization, etc., may also be provided as critical parameters. In the case of a mechanical temperature-sensitive, component temperature-induced changes of mechanical variables, such as shape or length, may also be considered as detectable characteristic parameters. These are preferably detected by means of electrical measuring methods. In this respect, temperature-dependent properties capable of being utilized as a switching effect are particularly preferred.

[0048] In the cases mentioned, the control and evaluation unit **7** may have the capability to detect a temperature-induced change in the characteristic component parameter critical in each case, and to determine the aging state of the exhaust gas catalytic converter **4**, based on characteristic curves.

[0049] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.

1.-**9**. (canceled)

10. A device for monitoring an exhaust gas catalytic converter in the exhaust system of an internal combustion engine, said device comprising:

measuring apparatus arranged in the exhaust system such that, in at least a predominant part of the operating range of the internal combustion engine, it assumes a temperature that is correlated with a temperature of the exhaust gas catalytic converter; and

a control evaluation unit that is coupled in communication with the measuring apparatus; wherein

the measuring apparatus has a temperature-sensitive component with a temperature dependent characteristic component parameter that changes either abruptly at a predetermined transition temperature or temperature range, or continuously in a predetermined way as a function of temperature; and

the control and evaluation unit can detect the characteristic component parameter and/or a change in the characteristic component parameter.

11. The device as claimed in claim **10**, wherein the measuring apparatus is fixedly connected to one of the exhaust gas catalytic converter, and a housing in which the exhaust gas catalytic converter is arranged.

12. The device as claimed in claim **10**, wherein the change that occurs in the characteristic component parameter is irreversible.

13. The device as claimed in claim **10**, wherein the change that occurs in the characteristic component parameter comprises a structural transformation of a material constituent of the temperature-sensitive component.

14. The device as claimed in claim **10**, wherein the temperature-sensitive component of the measuring apparatus is a passive electrical structural element.

15. The device as claimed in claim **10**, wherein the temperature-sensitive component is produced by thick-film technology.

16. The device as claimed in claim **10**, wherein the measuring apparatus comprises a plurality of temperature-sensitive components, and one of the following is true:

individual temperature-sensitive components differ from one another in terms of the transition temperature or temperature range of their characteristic component parameter; and

individual temperature-sensitive components have characteristic component parameters that change in time in a different way, as a function of the temperature.

17. The device as claimed in claim **10** wherein, the temperature-sensitive component is designed in such a way that the transition temperature or temperature range of its characteristic component parameter is correlated with a permissible upper operating temperature of the exhaust gas catalytic converter, or the change in the characteristic component parameter which occurs in the course of time is correlated with a parallel-running aging of the exhaust gas catalytic converter.

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