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(54) **METHOD AND DEVICE FOR THE DIAGNOSIS OF DEFECTS IN COMPONENTS OF CHASSIS SYSTEMS OF MOTOR VEHICLES**

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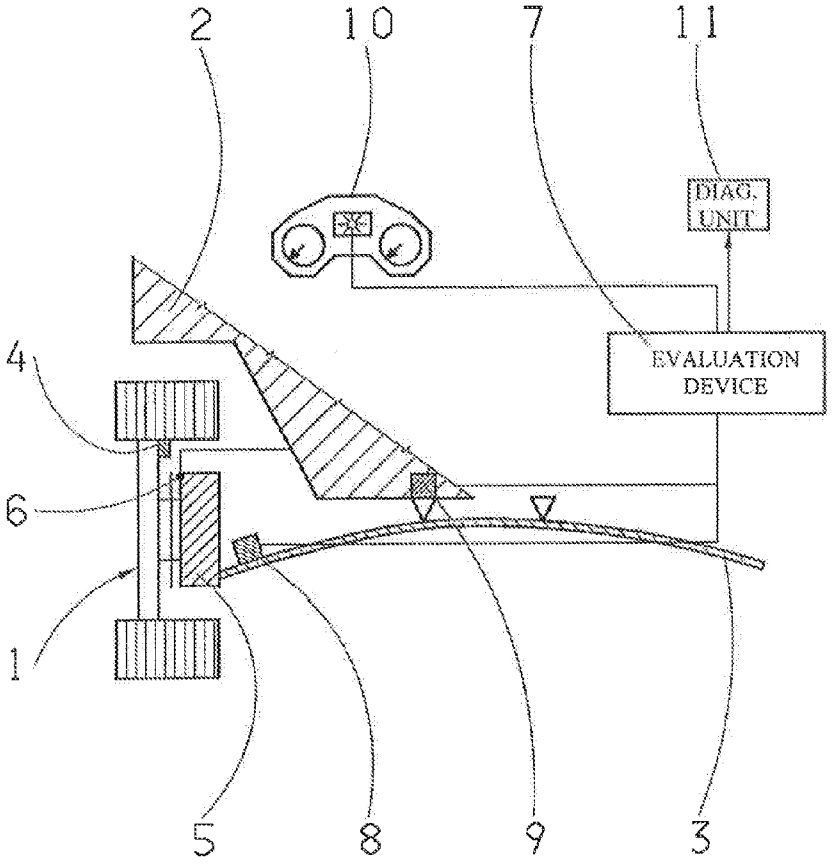
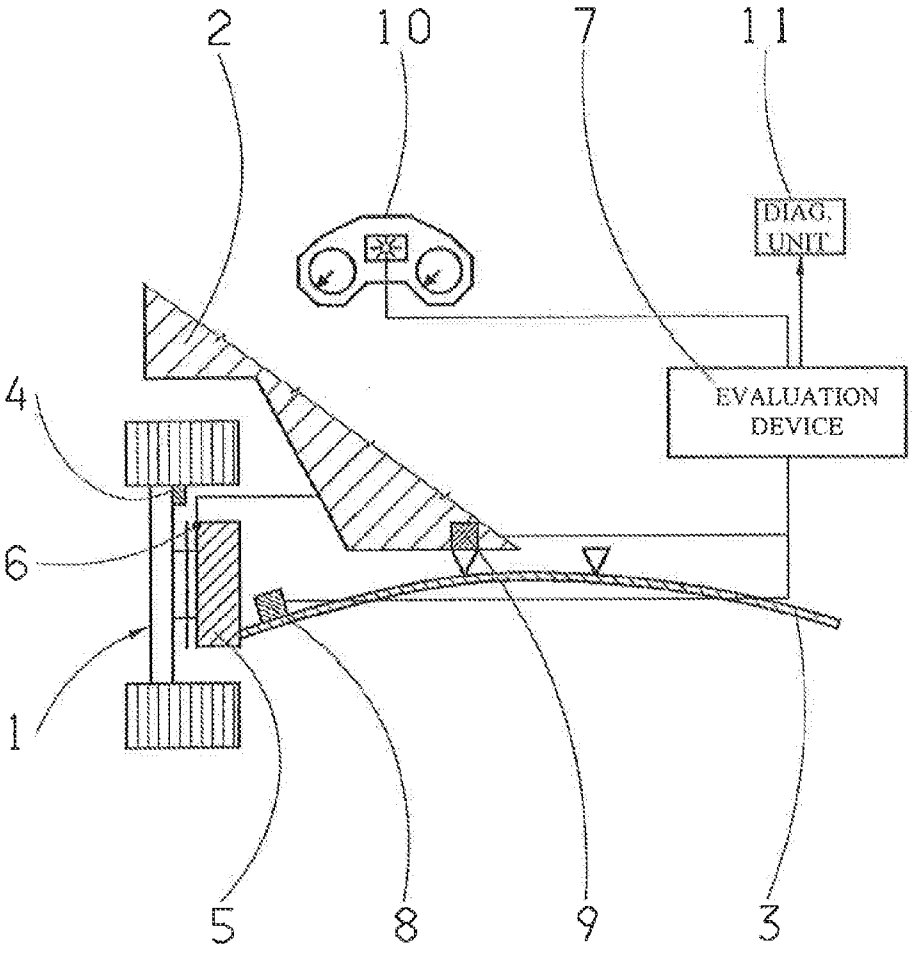
(57) **ABSTRACT**

A method for the diagnosis of defects in components of motor vehicle chassis systems. Vibrations produced by rotating components of the chassis system due to an imbalance are filtered such that the frequency range which depends on the wheel rotation speed and contains the imbalance-induced vibrations of the rotating components is filtered out. The signals from sensors associated with the component and arranged on the wheel carrier side and the vehicle body side, are received and stored. The amplitudes of these signals are sorted by increasing frequency and the mechanical impedance of the transmission chain is determined and compared with the known impedance of that component undamaged. If a deviation of the determined impedance for the component and the known impedance of the undamaged component is recognized, then the component is determined to have a defect and a flag is set.

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EVALUATION DEVICE
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METHOD AND DEVICE FOR THE DIAGNOSIS OF DEFECTS IN COMPONENTS OF CHASSIS SYSTEMS OF MOTOR VEHICLES

[0001] This application is a National Stage completion of PCT/EP2012/065113 filed Aug. 2, 2012, which claims priority from German patent application serial no. 10 2011 082 806.0 filed Sep. 16, 2011.

FIELD OF THE INVENTION

[0002] The invention relates to a method for the diagnosis of defects in components of chassis systems of motor vehicle. Furthermore, the invention relates to a device for the diagnosis of defects in components of chassis systems of motor vehicle.

BACKGROUND OF THE INVENTION

[0003] The chassis of a motor vehicle serves to guide the wheels and possibly also driveshafts, relative to a spring-mounted vehicle body. One end of the chassis is connected to the vehicle body whereas the other end of the chassis comprises fixtures for holding the wheels and possibly also shafts and other rotating components.

[0004] Due to manufacturing inaccuracies, rotating components, for example wheels, as a rule are affected by static and dynamic imbalance, which can be reduced by balancing weights but can never be completely eliminated. For that reason the guiding fixtures and bearings of rotating components are excited by a harmonically oscillating force amplitude, i.e. a time-variable force difference relative to the static force.

[0005] In motor vehicle chassis systems, the very slight harmonic vibrations caused by the imbalance of rotating components are masked by substantially larger stochastic vibrations resulting from roadway excitations, and are therefore seldom perceptible and can only be detected by measurement technology means.

[0006] Since the frequency of the vibrations produced due to imbalance depends on the rotational speed of the rotating components and therefore as a rule on the driving speed of the motor vehicle, the influence of such imbalance-induced vibrations can be filtered out by means of a filter, for example a band pass filter. Since during operation motor vehicles are accelerated from and braked back to rest and are driven at various speeds, all frequencies are excited up to a maximum frequency limited by the top speed of the vehicle, i.e. during constant acceleration the signal obtained is a so-termed sweep signal, i.e. a periodic signal which changes its frequency over a defined time from an initial value to a final value.

[0007] To determine the mechanical impedance of components prone to vibration or for system identification purposes, in most cases test signals are used, including also sweep signals, in order to analyze the system's response at various frequencies. Damage in components located in the transmission chain between the sensors for determining the mechanical impedance leads to altered system behavior, i.e. the system reacts to a given input signal with a different system response. Thus, under laboratory and test conditions the altered behavior of the structure can be recognized, which allows the presence of a defect to be deduced.

[0008] In a motor vehicle, however, on the one hand there are as a rule no test signals such as sweep signals, while on the other hand the use of stochastic signals, for example ones provoked by roadway excitations, results in considerable evaluation problems.

[0009] To increase the safety of motor vehicles, the recognition of damage in structural components is gaining importance, particularly in order to avoid dangerous and expensive consequential damage. From the prior art systems and methods are known, which evaluate vibration signals for the diagnosis of systems or components.

[0010] For example, DE 10 2008 016 746 A1 describes an arrangement for detecting and/or evaluating vibrations of bodies and/or structures that are moving and/or which comprise a drive, in particular vehicles or motor vehicles, the arrangement having at least one vibration sensor coupled to an evaluation unit. In this case the at least one vibration sensor comprises a measurement pickup arranged on the body or structure to detect its vibration behavior.

[0011] Moreover, DE 44 40 413 A1 describes an arrangement for monitoring the effectiveness of at least one shock-absorber fitted into a chassis of a vehicle, in particular a motor vehicle, during driving operation. This known arrangement comprises at least one measurement sensor operationally attached to the shock-absorber or on a vehicle component connected thereto, whose measurement signal gives a measure of an operating parameter that changes as the effectiveness of the shock-absorber decreases, and comprises also a data memory to be arranged in the vehicle for storing at least one limit value that defines an effectiveness limit, a monitoring circuit to be arranged in the vehicle, which, depending on the measurement signal from the measurement sensor and the limit value stored in the data memory, determines whether the effectiveness has fallen blow the effectiveness limit, and a display device which communicates with the monitoring circuit and indicates that the effectiveness has fallen below its limit.

[0012] In the context of DE 4 431 794 A1 a method for determining the properties of the shock-absorbers fitted in a motor vehicle is disclosed, wherein the motor vehicle is driven onto a ramp which is then lowered abruptly so that the motor vehicle drops onto a supporting base, whose distance below the ramp height corresponds to the residual rebound path determined by the design of the motor vehicle, and the variation of the so-termed wheel contact force acting upon the base when the wheel drops is determined. In this known method it is provided that the oscillation behavior of the vehicle body and in each case a wheel is measured, with the aim of being able, by combining the measurement results, to calculate the data that characterize the chassis of the motor vehicle, namely the body and wheel masses, the spring rigidity and the damping constants. Preferably, the oscillation behavior of the body and wheel of the axle of the motor vehicle to be tested is determined for each side of the axles being tested, by measuring the body and wheel bounce path that occurs.

[0013] Furthermore, DE 43 40 746 C2 describes a diagnosis arrangement for diagnosing a dynamic system, for example diagnosing a tire air pressure or determining a vehicle body weight, by detecting a defect of the dynamic system, the arrangement comprising a fault-determining device for estimating a composite fault vector which is the sum of an external and in internal fault vector on the basis of an internal condition vector of the dynamic system, and comprising also a correlation calculating device for calculating a cross-correlation between the estimated composite fault vec-

tor and the internal condition vector related to the internal fault, and a diagnosis device for specifying and diagnosing a corresponding faulty part of the dynamic system from the separated component related to the internal fault. In this case the correlation-calculating device is designed such that a correlation between an element of the composite fault vector and an element of the internal condition vector not correlated with the external fault is calculated, and from the element of the internal condition vector a component related to the internal fault is separated out. The external disturbance factor can be, for example, a road surface irregularity.

[0014] In addition, a method is known from DE 199 17 541 A1 for defect diagnosis in an object to be investigated, such as a rotating machine, by measuring a vibration produced by it. In this case a measurement signal produced by the object is picked up, an amplitude probability density function of a waveform of the measurement signal obtained is orthogonally expanded by a Gram-Charlier series and the Gram-Charlier series is calculated, in order to make a diagnosis of a defect in the object being investigated.

SUMMARY OF THE INVENTION

[0015] The objective of the present invention is to propose a method for the diagnosis of defects in components of motor vehicle chassis systems, which is based on the evaluation of vibration signals and which allows the use of diagnostic methods known under laboratory conditions in a motor vehicle.

[0016] This objective is achieved by a method and a device for the diagnosis of defects in components of motor vehicle chassis systems, in particular by implementing the method according to the invention.

[0017] Accordingly, a method is proposed for the diagnosis of defects in components of motor vehicle chassis systems, in which the vibrations produced due to imbalance, preferably by rotating components arranged on a wheel carrier, for example the wheels of the chassis system, are filtered by means of a band pass filter of the first or a higher order in such manner that the frequency range that depends on the driving speed and consequently on the wheel rotational speed is filtered out, this range containing the vibrations of the rotating component produced due to imbalance, wherein the driving speed-dependent frequency range is determined from the signals of a wheel rotational speed sensor, so that the middle of the filtered-out frequency range is determined by the frequency of the measured wheel rotational speed.

[0018] Frequency ranges can also be used additionally or alone, whose middle corresponds to a harmonic of the wheel rotational speed.

[0019] According to the invention, for the diagnosis of defects in components of a chassis system, for a specified measurement duration an evaluation device picks up and stores the signals from at least one sensor associated with the component to be diagnosed, which sensor is arranged on the wheel carrier, and from at least one sensor associated with the component to be diagnosed, which sensor is arranged on the vehicle body, such that the sensors deliver values for at least one measurable physical movement parameter such as movement path, acceleration, speed, angle, rotational speed, turning rate, extension, thrust and/or torsion. To store the data, the evaluation device comprises internal storage means; alternatively, the evaluation device can be connected to external storage means.

[0020] The amplitudes of the sensor signals are sorted in the evaluation device by increasing frequency, so that the mechanical impedance of the transmission chain, i.e. the resistance opposing the propagation of vibrations, can be determined. According to the invention, the sensors arranged on the wheel carrier and/or on the vehicle body can be associated with a plurality of components to be diagnosed.

[0021] The measurement duration is determined in that it corresponds to a time interval during which almost every frequency occurs, i.e. the time during which the speed of the vehicle and hence the rotational speed of the rotating components have been through all the values that can occur during normal operation of the vehicle. Preferably the measurement duration is determined dynamically, so that measurement ends when a specified frequency interval has been passed through.

[0022] Thereafter, the impedance of a component with which the sensors are associated, determined in this way, is compared in the evaluation device with the previously measured or known impedance of that component in its undamaged condition, which is stored in the evaluation device, and optionally also with further impedances of the component with known defects or damage, which are also known and stored in the storage means of the evaluation device, and in this case the closest agreement of impedances is identified and from this it is assumed that the component is in whichever condition is represented by the known impedance which corresponds most closely to the impedance determined.

[0023] When no recourse is had to known impedances of the component to be diagnosed with known defects, the impedance determined for the component to be diagnosed, with which the sensors are associated, is only compared with the impedance of the component in its undamaged condition.

[0024] By virtue of the optional comparison of the impedance determined with other, known impedances of the component to be diagnosed, where those impedances correspond to known defects or damage, in the event that a defect is detected it is advantageously possible to obtain additional information about the severity, type or location of the defect.

[0025] According to the invention, it is provided that so long as the impedance determined for the component to be diagnosed agrees with the impedance of the component in its undamaged condition, no fault code is emitted, whereas if there is no agreement, this being recognized if a threshold value for the difference between the impedance determined and the impedance of the component in its undamaged condition is exceeded, and in the case when the impedance determined is compared with other, known impedances of the component with known defects and an agreement is recognized between the impedance determined and an impedance of the component in a damaged condition, then a defect of the component to be diagnosed is recognized and a fault-flag is generated which, for example by means of the vehicle's display unit, calls for an inspection and optionally produces a visual or acoustic signal to alert the driver.

[0026] In a further development of the invention, when a defect is recognized in a component to be diagnosed a further fault code is generated which, during the inspection of the motor vehicle, can be read out by a diagnosis unit in order to provide further information about the defect, for example in the event that an agreement of the impedance determined with the impedance of the component in a damaged condition is recognized, such information concerning the severity, type or location of the defect, so that depending on the type of defect,

by virtue of the further fault code safety measures can be initiated, such as limiting the driving speed or even emergency braking.

[0027] According to the invention, the imbalance of the rotating components, for example a wheel, can be increased or adjusted by means of an eccentric; in particular this can be the case when the residual imbalance of the rotating component after balancing is very slight.

[0028] The device according to the invention for the diagnosis of defects in components of motor vehicle chassis systems accordingly comprises an evaluation device with internal storage means, at least one sensor arranged on a wheel carrier and associated with at least one component to be diagnosed and at least one sensor arranged on the vehicle body and associated with at least one component to be diagnosed, wherein the at least one sensor on the wheel carrier and the at least one sensor on the vehicle body deliver input signals for the evaluation device and wherein the output signal from at least one wheel rotational speed sensor is also transmitted to the evaluation device. In this case the at least one wheel rotational speed sensor can be one that is present in any event in the vehicle, and the evaluation device is then connected to the vehicle's computer or to the vehicle's databus system. Alternatively, the device for the diagnosis of defects in rotating components of chassis systems can comprise at least one wheel rotational speed sensor of its own.

[0029] The device according to the invention can be permanently and securely installed in the vehicle in the manner of an on-board diagnosis unit. Alternatively, the necessary sensors and optionally the eccentric for producing an adjustable imbalance can be attached temporarily to the components or brought into functional connection with the vehicle, in which case the evaluation device is designed as an external evaluation unit which is connected temporarily to the vehicle in order to effect a diagnosis for maintenance purposes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Below, an example of the invention is explained in more detail with reference to the sole FIGURE, which shows a schematic view of a wheel of a motor vehicle, the vehicle body, and the components of a device for the diagnosis of defects in the components of motor vehicle chassis systems.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] In the attached FIGURE a wheel of an motor vehicle is indexed **1** and the vehicle body is indexed **2**. In addition, a chassis component to be diagnosed, which can for example be in the form of a transverse leaf spring made of a fiber composite material, is indexed **3**. On the wheel **1** an imbalance **4** is indicated, since all rotating components in a chassis have some slight residual imbalance even after being balanced. As already explained, the imbalance of the rotating component to be diagnosed can optionally be increased or adjusted by means of an eccentric. Furthermore, in the attached FIGURE the wheel carrier is indexed **5**.

[0032] For the diagnosis of defects in the chassis component **3**, according to the invention the vibrations produced by the rotating wheel **1** due to its imbalance **4** are filtered in an evaluation device **7** by means of a band pass filter of the first or a higher order, in such manner that the frequency range which depends on the wheel rotational speed, which contains the vibrations of the wheel **1** caused by the imbalance, is filtered out. During this the frequency range that depends on the wheel rotational speed is determined by means of the signals from a wheel rotational speed sensor **6**, so that the middle of the filtered-out frequency range is determined by the frequency of the wheel rotational speed measured by the wheel rotational speed sensor **6**.

[0033] The evaluation device **7** is connected to a sensor **8** arranged on the wheel carrier side and to a sensor **9** arranged on the vehicle body side, these sensors being associated with the chassis component **3** to be diagnosed and delivering, as input signals, values for at least one measurable physical movement parameter, for example a path, acceleration, speed, angle, rotational speed, turning rate, extension, thrust and/or torsion.

[0034] Since over a certain measurement duration almost all the frequencies that can occur during the operation of the motor vehicle will have occurred, in the evaluation device **7** the amplitude of the sensor signals are sorted by increasing frequency and the mechanical impedance of the transmission chain, i.e. the resistance that opposes the propagation of the vibrations, is determined.

[0035] In a subsequent step the mechanical impedance of the chassis component **3** with which the sensors **8**, **9** are associated, determined as described, is compared in the evaluation device **7** with the known impedance of the chassis component **3** in its undamaged condition and optionally also with other known impedances of the chassis component **3** when it has known defects or damage, and in the latter case the closest agreement of the impedance is identified and it is assumed that the chassis component **3** is in whichever condition is represented by the known impedance which corresponds most closely to the impedance determined.

[0036] If a deviation of the impedance determined for the chassis component **3** from its known impedance in the undamaged condition is recognized, and if this deviation exceeds a specified threshold value, a defect of the chassis component **3** is recognized and a fault-flag is generated, which optionally appears on the vehicle's display unit **10** as a call for inspection and also optionally produces a visual or acoustic signal to alert the driver.

[0037] In the event that an agreement of the impedance determined with the impedance of the component in a damaged condition is recognized, a further fault code is produced which during the inspection of the motor vehicle, can be read out by a diagnosis unit **11** in order to provide further information about the defect, for example the severity, type or location of the defect. Depending on the type of the defect, the further fault code can initiate safety measures in the vehicle.

INDEXES

[0038] **1** Wheel
[0039] **2** Vehicle body
[0040] **3** Chassis component
[0041] **4** Imbalance
[0042] **5** Wheel carrier
[0043] **6** Wheel rotational speed sensor
[0044] **7** Evaluation device
[0045] **8** Sensor arranged on the wheel side
[0046] **9** Sensor arranged on the vehicle body side
[0047] **10** Vehicle display unit
[0048] **11** Diagnosis unit

1-13. (canceled)

14. A method of diagnosis of a defect in a component of a motor vehicle chassis system, the method comprising the steps of:

filtering vibrations, that are produced by at least one rotating component (**1**) due to an imbalance (**4**), with a band pass filter of either a first order or a higher order to filter out a frequency range which depends on a speed of rotation of the rotating component and which contains the imbalance-induced vibrations of the rotating component, and the frequency range which depends on a speed of rotation of the rotating component including either frequency of the rotational speed or a harmonic of the rotational speed of the rotating component;

receiving and storing signals, via an evaluation device, over a specified measurement duration the signals being transmitted from at least one sensor (**8**) that is arranged on a wheel carrier side and is associated with the component (**3**) to be diagnosed and from at least one sensor (**9**) that is arranged on a vehicle body side and is associated with the component (**3**) to be diagnosed, the sensors (**8**, **9**) transmitting values for at least one measurable physical movement parameter, such that in the evaluation device (**7**), amplitudes of the sensor signals are sorted by increasing frequency and mechanical impedance of the transmission chain, i.e. resistance that opposes propagation of the vibrations, is determined;

comparing the determined mechanical impedance of the component (**3**) to be diagnosed with a known impedance of the component (**3**) to be diagnosed when the component (**3**) to be diagnosed is in an undamaged condition; and

if a deviation of the impedance determined for the component (**3**) to be diagnosed from the known impedance thereof in the undamaged condition exceeds a specified threshold value, then

recognizing a defect of the component (**3**) to be diagnosed,

emitting a fault code, and

generating a fault-flag.

15. The method of diagnosis of the defect in the component of the motor vehicle chassis system according to claim **14**, further comprising the step of additionally comparing, in the evaluation device (**7**), the impedance determined for the component (**3**) to be diagnosed with known impedances of the component (**3**) to be diagnosed, when the component has either known defects or damage, identifying a closest agreement with the known impedances, and assuming, from the closest agreement, that the component (**3**) to be diagnosed is in whichever condition is represented by the known impedance that most closely corresponds to the impedance determined, and if an agreement of the impedance determined with the impedance of the component (**3**) to be diagnosed when the component is in a damaged condition is recognized, then producing a further fault code which can be read out by a diagnosis unit (**11**), during an inspection of the motor vehicle, to obtain further information about the defect, whereby, depending on the type of defect, the further fault code can also initiate safety measures in the vehicle.

16. The method of diagnosis of the defect in the component of the motor vehicle chassis system according to claim **14**, further comprising the step of, as a result of the fault-flag in a display unit of the vehicle, requesting an inspection.

17. The method of diagnosis of the defect in the component of the motor vehicle chassis system according to claim **14**, further comprising the step of, as a result of the fault-flag in a display unit of the vehicle, requesting an inspection and producing one of a visual and an acoustic signal to alert a driver.

18. The method of diagnosis of the defect in the component of the motor vehicle chassis system according to claim **14**, further comprising the step of transmitting values for at least one of movement path, acceleration, speed, angle, rotation speed, turning rate, extension, thrust and torsion with the at least one sensor (**8**) arranged on the wheel carrier side and the at least one sensor (**9**) arranged on the vehicle body side deliver.

19. The method of diagnosis of the defect in the component of the motor vehicle chassis system according to claim **14**, further comprising the step of dynamically determining the specified measurement duration so that measurement ends when a specified frequency interval occurs.

20. The method of diagnosis of the defect in the component of the motor vehicle chassis system according to claim **14**, further comprising the step of either increasing or adjusting the imbalance of the rotating components (**1**) by an eccentric.

21. A device for diagnosis of a defect in a component of motor vehicle chassis system, the device comprising:

an evaluation device (**7**) having either an internal storage means or being connected to an external storage means,

at least one sensor (**8**) associated with at least one component (**3**) to be diagnosed and arranged on a wheel carrier side,

at least one sensor (**9**) associated at least with the component (**3**) to be diagnosed and arranged on a vehicle body side such that the at least one sensor (**8**) on the wheel carrier side and the at least one sensor on the vehicle body side produce input signals for the evaluation device (**7**), and

an output signal from at least one wheel rotational speed sensor (**6**) also being sent to the evaluation device (**7**) so that in the evaluation device (**7**), vibrations produced by rotating components (**1**), owing to an imbalance (**4**), are filterable by a band pass filter of either a first order or a higher order such that a frequency range that depends on wheel rotational speed, which contains vibrations of the rotating components induced by imbalance, are filtered out,

the frequency range that depends on the driving speed being determinable by the signals from the wheel rotational speed sensor (**6**) so that a middle of the filtered-out frequency range is determined by the frequency of the measured wheel rotational speed, and in the evaluation device (**7**), amplitudes of the sensor signals are sorted by increasing frequency and mechanical impedance of the transmission chain are determinable, the evaluation device (**7**) comparing the mechanical impedance determined for the component (**3**) to be diagnosed with a known impedance thereof when the component (**3**) to be diagnosed is in an undamaged condition, and if a deviation of the impedance determined for the component (**3**) from the known impedance thereof in the undamaged condition is recognized, the deviation exceeding a specified threshold value, a defect of the component (**3**) to be diagnosed is recognized and the evaluation device (**7**) emits a fault code and generates a fault-flag.

22. The device for diagnosis of the defect in the component of motor vehicle chassis system according to claim **20**, wherein further known impedances of the component (**3**) to be diagnosed, which characterize either known defects or

damage, are stored by the storage means of the evaluation device (**7**), and the impedance determined for the component (**3**) to be diagnosed is compared with the further known impedances of the component (**3**) to be diagnosed, when the component has either a defect or is damaged, whereby a closest agreement of the impedance is identified and the device assumes that the component (**3**) is in whichever condition is represented by the known impedance that most closely corresponds to the determined impedance.

23. The device for diagnosis of the defect in the component of motor vehicle chassis system according to claim **20**, wherein the device is either installed permanently and securely in a motor vehicle as an on-board diagnosis system, or the sensors (**8**, **9**) and an eccentric for producing an adjustable imbalance (**4**) are either temporarily attachable to the corresponding components or are functionally connectable with the vehicle so that, in a latter case, the evaluation device (**7**) is designed as an external evaluation device (**7**) which is temporarily connectably to the vehicle in order to facilitate diagnosis during maintenance.

24. A method of diagnosis of a defect in rotating a component of a vehicle, the method comprising the steps of:

measuring, during operation of the component, at least one first movement parameter of an element that drives the rotating component;

measuring, at least one second movement parameter, either of the rotating component or of a component following the rotating component; and

comparing the two movement parameters to determine the defect in the rotating component of the vehicle.

25. The method according to claim **23**, further comprising the step of determining the imbalance of the rotating component by virtue of the comparison of the first and the second movement parameters which are at least one of rotation speed, torque, thrust and torsion.

26. The method according to claim **23**, further comprising the step of filtering a time variation of the at least one second movement parameter by a band pass filter whose transmission frequency band includes the frequency of the at least one first movement parameter.

27. The method according to claim **23**, further comprising the step of defining the at least one first movement parameter as a parameter that characterizes the movement of a wheel of the vehicle.

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