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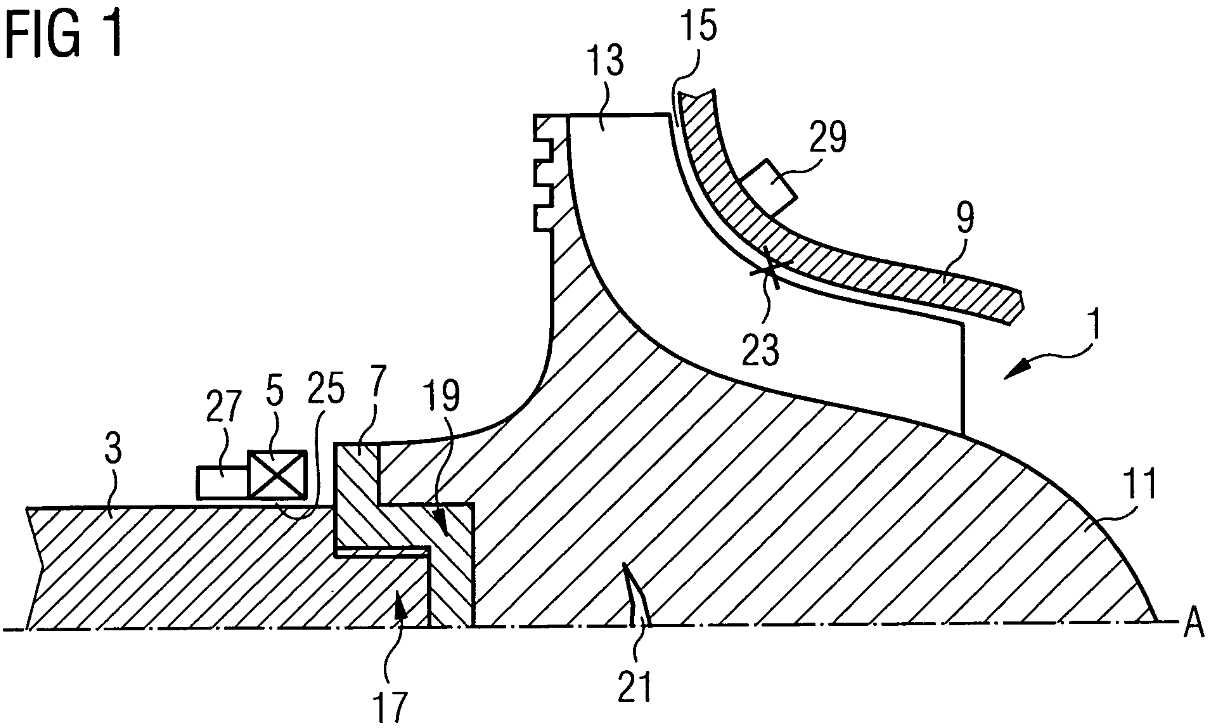
(54) **Impeller arrangement and method of condition detection in an impeller arrangement**

(57) An impeller arrangement is provided which comprises an impeller casing (9), an impeller (1), a shaft (3) fixed to the impeller (1) and a shaft bearing (5). It further comprises a condition detection system with one or more sensors (27, 29) which is/are located and designed such as to be able to detect acoustic waves in the impeller casing (9) and/or the impeller (1) and/or the shaft (3) and/or in the shaft bearing (5).

FIG 1



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Description

[0001] The present invention relates to an impeller arrangement comprising an impeller casing, an impeller, a shaft fixed to the impeller and a shaft bearing. In addition, the present invention relates to a method of condition detection in such an impeller arrangement.

[0002] Impeller arrangements are used, in particular, in turbo chargers and centrifugal compressors. Typically, a turbo charger compressor impeller is made from aluminium and has an average life span of about 50,000 hours. The life span of such an impeller tends to be governed by creep of the impeller material. Faults, such as cracks and rubs, however, can increase creep or fatigue which will lead to a shortened life span of the impeller and to unwanted shaft movement. In addition, a degradation in lubrication quality and bearing wear can also shorten the life span of the impeller arrangement. The mentioned faults can, in particular, lead to a sudden failure in the impeller performance which in turn could lead to damage at the device using the impeller. Therefore, impellers with the above-mentioned faults need to be repaired or replaced in time.

[0003] It is therefore a first objective of the present invention to provide an improved impeller arrangement. It is a second objective of the present invention to provide a method of detecting the condition of an impeller arrangement.

[0004] The first objective is solved by an impeller arrangement according to claim 1. The second objective is solved by a method of condition detection in an impeller arrangement as claimed in claim 9. The depending claims contain further developments of the invention.

[0005] An inventive impeller arrangement comprises an impeller casing, an impeller, a shaft fixed to the impeller and a shaft bearing. In addition, it comprises a condition detection system with one or more sensors which is/are located and designed such as to be able to detect acoustic waves in the impeller and/or the shaft and/or in the shaft bearing and/or in the impeller casing.

[0006] The invention is based on the following observations:

[0007] A dynamic physical event, such as cracking or rubbing, leads to the emission of a high frequency acoustic wave in a solid or liquid medium. These waves can easily be detected by suitable sensors, for example, by piezoelectric sensors. In addition, not only the actual cracking or rubbing but also the presence of a crack or a rubbing area lead to measurable acoustic waves. The same is true for a degradation of lubrication quality at the bearing of the shaft and for the presence of bearing wear. All of these effects can be determined by measuring the acoustic waves propagating through the impeller casing and/or the impeller and/or the shaft and/or the shaft bearing in a non-intrusive manner, e.g. at the impeller casing or at the shaft bearing. Note, that the waves propagating through the shaft would be transmitted from the shaft to the shaft bearing through the oil film there between and from the shaft bearing to the casing so that they can be detected at the shaft bearing or the casing. Waves propagating through the impeller would be transmitted to the shaft and from there as indicated above. Hence, the provision of sensors for measuring acoustic waves propagating through the components in a non-intrusive manner can be used for the early detection of faults. Such an early detection may allow the faulty component to be repaired before the fault becomes so severe that repairing is no longer possible. In addition, if the detected fault is severe, the early detection allows the faulty component to be replaced by a new one before it can lead to more severe damage of the device the impeller arrangement is used in.

[0008] As already mentioned, at least one piezoelectric sensor may be used as a sensor to detect acoustic waves, in particular high frequency acoustic waves, in the impeller casing and/or the impeller and/or the impeller shaft and/or the impeller bearing.

[0009] A sensor for sensing the acoustic waves could be located, for example, such as to adjoin the impeller bearing or an impeller casing which is part of the impeller arrangement. When the sensor adjoins the bearing it would be particularly sensitive to a degradation of lubrication or to bearing or shaft wear. However, cracks and rubs at the impeller could lead to an unbalance of the impeller which in turn would affect the shaft and could be measured by the sensor adjoining the bearing. If the sensor is located such as to adjoin the impeller casing it would be particularly sensitive to rubs at the impeller vanes. However, cracks, a degradation of lubrication quality at the shaft bearing, bearing or shaft wear could also be detected by their effect on the impeller casing.

[0010] If a number of sensors are distributed, for instance in the form of a sensor array, over the impeller bearing and/or over the impeller casing the location of the fault can be determined from the signals measured by the sensors. This allows an assessment of the possible impact of the fault which in turn allows the suitable measures to be assigned to react to the detected fault.

[0011] The condition detection system may comprise a frequency analysing unit connected to the sensor or the sensors which would allow the discrimination between the different types of acoustic waves propagating in the impeller components. Such a discrimination would offer the possibility of determining the type of fault from the type of acoustic waves.

[0012] The frequency analyser could further be part of a monitoring unit connected to the sensor/s and/or to the frequency analysing unit. The monitoring unit would offer the possibility of continuously monitoring the condition of the impeller arrangement and would, in turn, allow the detection of any fault in its earliest state detectable by the sensor or sensors.

[0013] Furthermore, the analysing unit may be connected to a recognition unit which is designed such as to recognise a fault from the analysing result and to output a fault signal if a fault is recognised.

[0014] In the inventive method of condition detection for an impeller arrangement comprising an impeller casing, an impeller, a shaft fixed to the impeller and a shaft bearing acoustic waves propagating through the impeller casing and/or the impeller and/or the shaft and/or the shaft bearing are detected and the condition of the impeller arrangement is established on the basis of the detected acoustic waves.

[0015] Establishing the condition of an impeller arrangement on the basis of acoustic waves propagating through the components offers the possibility of non-intrusively detecting faults in the impeller components at an early stage of the faults. As has been mentioned above with respect to the inventive impeller arrangement, detection of the acoustic waves, in particular of high frequency acoustic waves, could be achieved by using piezoelectric sensors.

[0016] The acoustic waves could be analysed to classify the detected faults and a fault type could be established from the analysis result. This further development of the invention would not only offer the possibility of detecting a fault but also discriminating between different fault types which would, in turn, allow for a more adapted reaction to a detected fault.

[0017] In the field, the inventive method can be used to monitor the condition of an impeller arrangement and to establish a fault signal on the basis of the detected condition of the impeller arrangement. It also becomes possible to find any occurring faults in the impeller, the shaft or the shaft bearing at their earliest detectable states.

[0018] If an acoustic wave is detected at different locations in the impeller arrangement it also becomes possible to locate the fault causing the acoustic wave.

[0019] Further features, properties and advantages of the present invention will become clear from the following description of embodiments of the invention in conjunction with the accompanying drawings.

[0020] Figure 1 shows an inventive impeller arrangement in a sectional view.

[0021] Figure 2 shows a block diagram of the condition detection system used in the impeller arrangement.

[0022] An inventive impeller arrangement is shown in Figure 1. The figure shows, in a section along the rotational axis A of the impeller arrangement, an impeller 1, a shaft 3 connected to the impeller 1 and a shaft bearing 5 which rotatably supports the shaft 3. The shaft 3 is connected to the impeller 1 via an impeller insert 7.

[0023] The impeller 1 comprises an impeller hub 11 which is surrounded by an impeller casing 9 that is spaced from the hub 11 so as to form a flow path between the housing 9 and the impeller hub 11. Impeller vanes 13 extend from the impeller hub 11 towards the impeller casing 9. Between the casing 9 and the vanes 13 a gap 15 remains which is kept as small as possible in order to minimise leakage of a gas which is to be compressed by the rotating impeller when flowing through the space between the hub 11 and the casing 9.

[0024] The impeller 1 is usually made of an aluminium alloy in order to keep its mass low. The shaft 3 in contrast is usually made of steel in order to provide high strength for the shaft which is usually a driving shaft connected to a driving turbine. The shaft 3 is screwed into an inner cavity 17 of the impeller insert 7 which is usually also made of steel. The impeller insert 7 itself is held in a cavity 19 of the impeller hub 11 by an interference fit. In the context of the present invention, the impeller insert 7 is regarded as being a part of the shaft 3.

[0025] During the operation of the described impeller arrangement cracks may occur, for example in the hub 11, as indicated by reference numeral 21. Moreover, a rub may occur between the vane 13 and the casing 9. Such cracks or such rubs would induce high frequency acoustic waves in the material of the impeller 1 and/or the material of the impeller casing 9. Moreover, the acoustic waves, induced in the impeller 1 would also be transmitted to the shaft 3 and from there, across the oil film, to the shaft bearing 5. Another source of high frequency acoustic waves would be a degradation of lubrication in the bearing 5, as indicated by reference numeral 25, or by shaft or bearing wear. Those acoustic waves would be induced in the shaft 3 and also be transmitted across the oil film to the shaft bearing 5 and from there to the impeller casing 9.

[0026] Acoustic waves caused by a crack 21 would propagate through the hub 11, the insert 7 and the shaft 3 to the bearing 5. According to the present embodiment, a piezoelectric sensor 27 is located adjacent to and is adjoining the bearing 5. By this piezoelectric sensor 27 the acoustic waves present in the shaft 3 or the bearing 5 can be detected. In addition, acoustic waves originating from the hub 11, which would be transmitted to the bearing 5 as described above, would also be detected by this piezoelectric sensor 27.

[0027] A further piezoelectric sensor 29 is, in the present embodiment, located on the casing 9 close to the position of the impeller vanes 13. If, for example, a rub 23 occurs between the impeller vane 13 and the casing 9 this would introduce high frequency acoustic waves into the casing 9 which would then easily be detected by the piezoelectric sensor 29. In addition, the rub 23 would also introduce high frequency acoustic waves into the impeller 1 which would be transmitted through the hub 11, the insert 7 and the shaft 3 to the bearing 5. Acoustic waves caused by a rub 23 could, therefore, be detected by the piezoelectric sensor 27 located adjacent to the bearing 5 as well as by the piezoelectric sensor 29 located adjacent to the casing 9.

[0028] The different kinds of damage or faults described above would cause high frequency acoustic waves which are different to each other. Therefore, by analysing the generated acoustic waves one can discriminate between the different sources of the acoustic waves, i.e. between the different faults.

[0029] In the inventive impeller arrangement the piezoelectric sensors 27, 29 are used for detecting the impeller arrangement's condition. In a special embodiment, the condition of the impeller arrangement can be monitored continuously, and a warning signal could be given out in the case of a fault being detected.

[0030] The condition detection system used in the impeller arrangement is schematically shown in the form of a block diagram in Figure 2. In the present embodiment, the condition detection system comprises, besides the piezoelectric sensors 27, 29, a frequency analyser 31 which is connected to the sensors 27, 29 for receiving signals representing the detected acoustic waves. The frequency analyser 31 may, for example, be a Fourier analyser which outputs a Fourier spectrum of the sensed acoustic waves. In the present embodiment the condition detecting system further comprises a memory 33 and a comparator 35. The memory could, for instance, be a non-volatile storage medium. It stores Fourier spectra for acoustic waves generated by different types of faults. For example, Fourier spectra for acoustic waves generated by cracks, rubs, lubrication degradation and bearing wear may be stored. The comparator 35 is connected to the Fourier analyser 31 for receiving the Fourier spectrum of the analysed acoustic wave and to the storage medium 33 for receiving the Fourier spectra stored therein. It is designed to compare the spectrum received by the frequency analyser 31 to the spectra stored in the storage medium 33 and to output a fault signal if any of the stored spectra matches the spectrum provided by the frequency analyser. The output of the comparator 35 could then be used to trigger a warning signal.

[0031] The condition detection system could be implemented such that it continuously monitors the condition of the impeller arrangement and to output a warning signal if an acoustic wave is detected the Fourier spectrum of which corresponds to one of the Fourier spectra stored in the storage medium 33. However, the condition detection system does not necessarily need to be implemented such as to continuously monitor the condition of the impeller arrangement. Instead, it could be implemented such as to provide information about the impeller arrangement's condition only on demand, for instance during an inspection.

[0032] Furthermore, the comparator 35 may be implemented such as to be able to output different warning signals depending on which of the stored Fourier spectra matches the Fourier spectrum received from the frequency analyser 31. By this measure the output of the comparator 35 would already distinguish between different fault conditions of the impeller arrangement, which could, for example, be used to trigger different warning signals for different faults.

[0033] Although only two piezoelectric sensors 27, 29 have been described with respect to the present embodiments, a single piezoelectric sensor, located for example at the bearing 5, would be enough to detect the condition of the impeller arrangement. However, a higher number of piezoelectric sensors offer the possibility of detecting the location of the fault which causes the detected acoustic waves. Therefore, a number of piezoelectric sensors 29, could, for example, be distributed over the impeller casing 9 in its circumferential and/or its axial direction. In addition, a number of piezoelectric sensors 27 could be distributed over the bearing 5. By using such arrays of sensors it becomes possible to locate the position of the fault which causes the acoustic waves.

[0034] Although the piezoelectric sensors have been described to be located at the impeller casing and the bearing with respect to the present embodiment, sensors could be located at all non-moving elements of the impeller arrangement to which the described acoustic waves can be transmitted. Moreover, sensors could, in principle, also be located in or at a moving part of the impeller arrangement, for example, in or at the impeller or the shaft, if wireless signal transmission from the sensor is considered.

[0035] With the inventive impeller arrangement and the inventive method of detecting the condition of an impeller arrangement it becomes possible to detect the condition of an impeller arrangement and to detect faults early on in a non-intrusive manner.

Claims

1. An impeller arrangement comprising an impeller casing (9), an impeller (1), a shaft (3) fixed to the impeller (1) and a shaft bearing (5),
   characterised in
   a condition detection system with one or more sensors (27, 29) which is/are located and designed such as to be able to detect acoustic waves in the impeller casing (9) and/or the impeller (1) and/or the shaft (3) and/or in the shaft bearing (5).

2. The impeller arrangement as claimed in claim 1,
   characterised in that
   at least one piezoelectric sensor (27, 29) is used as sensor to detect the acoustic waves.

3. The impeller arrangement as claimed in claim 1 or claim 2,
   characterised in that
   a sensor (27) adjoins the shaft bearing (5).

4. The impeller arrangement as claimed in any of the preceding claims,
   characterised in that
   a sensor (29) adjoins the impeller casing (9).

5. The impeller arrangement as claimed in any of the preceding claims,
   characterised in that
   a number of sensors (27, 29) are distributed over the shaft bearing (5) and/or over the impeller casing (9).

6. The impeller arrangement as claimed in any of the

preceding claims,
characterised in
a frequency analysing unit (31) is connected to the sensor or the sensors (27, 29).

7. The impeller arrangement as claimed in any of the preceding claims,
characterised in that
the frequency analysing unit (31) is part of a monitoring unit connected to the sensor or the sensors (27, 29).

8. The impeller arrangement as claimed in claim 6 or claim 7,
characterised in
a fault recognition unit (33, 35) which is connected to the frequency analysing unit (31) and designed such as to recognise a fault from the analysing result and to output a fault signal if a fault is recognised.

9. A method of condition detection for an impeller arrangement comprising an impeller casing (9), an impeller (1), a shaft (3) fixed to the impeller (1) and a shaft bearing (5),
characterised in that
acoustic waves propagating through the impeller casing (9) and/or the impeller (1) and/or the shaft (3) and/or the shaft bearing (5) are detected and the condition of the impeller arrangement is established on the basis of the detected acoustic waves.

10. The method as claimed in claim 9,
characterised in that
the acoustic waves are analysed to detect faults and a fault type is established for a detected fault based on the analysis result.

11. The method as claimed in claim 9 or claim 10,
characterised in that
the condition of the impeller arrangement is monitored and a fault signal is established on the basis of the detected condition of the impeller arrangement.

12. The method as claimed in any of the claims 9 to 11,
characterised in that
acoustic waves are detected at different locations in the impeller arrangement.

FIG 1

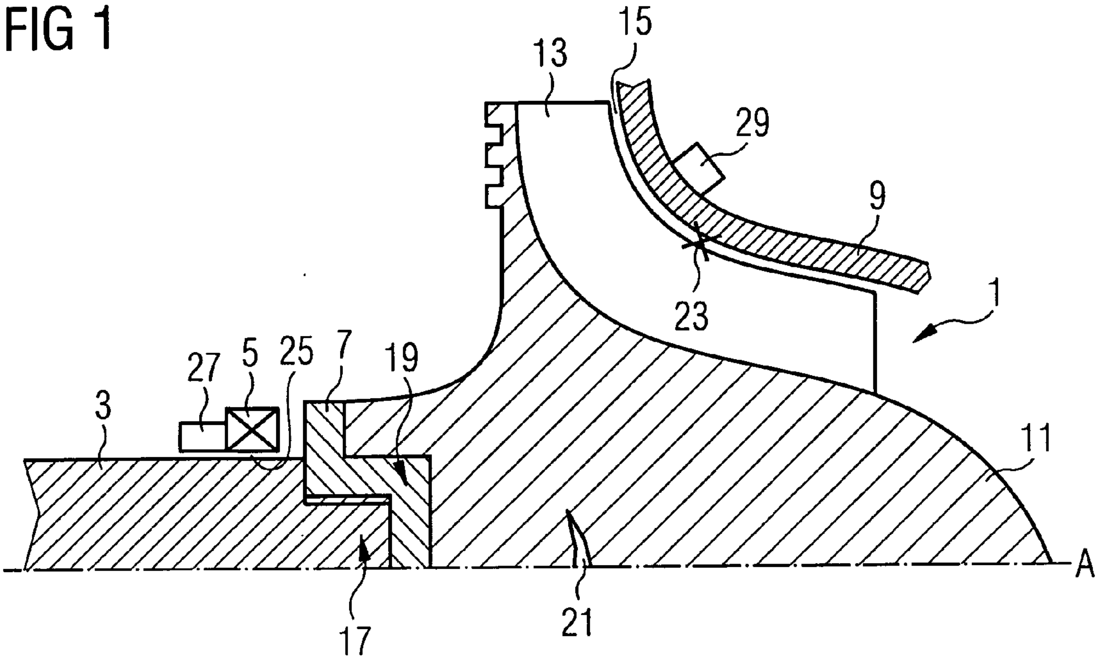
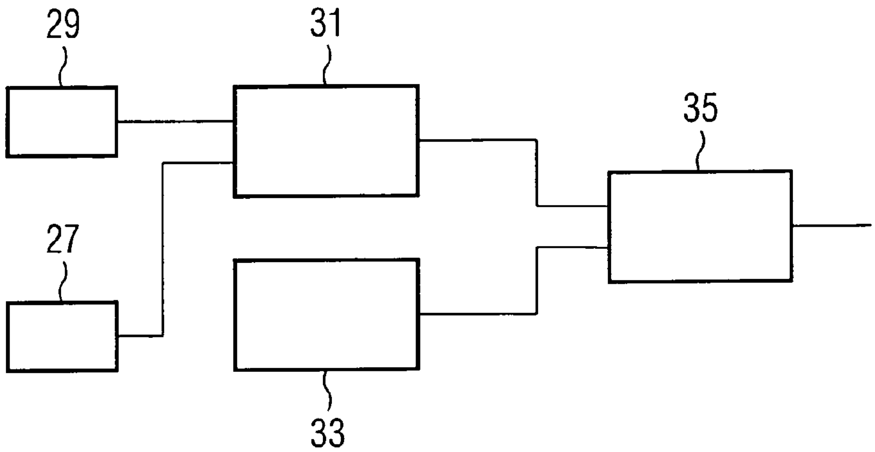


FIG 2



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EUROPEAN SEARCH REPORT

Application Number
EP 07 01 3712

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F04D
G01M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 December 2007	Giorgini, Gabriele

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CATEGORY OF CITED DOCUMENTS

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