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(54) Title: PIEZO ELECTRIC SENSOR FOR MONITORING ROTATIONAL PARTS

(57) **Abstract:** A sensor for monitoring rotational parts is provided which comprises a piezo-electric element arranged in contact with a part to be monitored and which generates an output signal in response to rotation of the part or of a sub-element of the part. In a preferred embodiment the part in question is a rotary bearing, and the piezo-electric element is provided as part of an annular ring which fits around the outer casing of the bearing, and which provides a sinusoidal output signal corresponding to the ball bearings or roller travelling around the bearing.

# PIEZO ELECTRIC SENSOR FOR MONITORING ROTATIONAL PARTS

## Technical Field

The present invention relates to a method and a sensor for monitoring and more particularly to a piezo electric sensor for such purpose.

## Background to the Invention

Monitoring rotational parts is a well known technique and occurs in a number of different spheres of activity such as the balancing of shafts and wheels. Usually, the monitoring is achieved by means of a separate apparatus within which the part to be monitored is positioned. In situ monitoring is difficult to achieve although it is accepted that the ideal location for monitoring apparatus is in situ. However, most installations are such as to make it not commercially viable to reshape or replace a housing to accommodate the monitoring apparatus. This is particularly true in the case of the monitoring of rotary bearings for wear.

## Prior Art

In order to try and overcome these problems, in the case of rotating parts it is known to assess the condition by means of sound using a conductor such as a screwdriver as a form of stethoscope. Later advances in diagnostic systems have involved the use of sensitive microphones and laser vibrometry. These systems are limited in use by size and cost but also by the difficulty of removing background vibrations. Optical systems in particular face particular problems due to the amplitude of background vibrations being in some cases of the same order of magnitude as the laser light being used to detect the vibrations.

It is an object of the present invention to monitor a rotational part in such a manner that external noise can be eliminated and a high signal output can be achieved.

The present invention proposes the use of an electro-mechanical transducer arranged to contact a rotary part to be monitored and to generate an electrical signal as a result of motion of the part.

According to the present invention, there is provided a sensor for monitoring rotational parts comprising a piezo-electric element arranged to contact a part to be monitored, and to generate an electrical output signal as a result of either: rotary motion of the part; or rotary motion of one or more sub-elements of the part.

By "part" we mean either a single component which itself may rotate, such as for example a shaft or axle, or a collection of individual components which function together to form a part which performs a function, such as a bearing, or a shaft provided within a bore or tube. In the latter meaning the "part" is provided with "sub-elements" which may rotate, and by "sub-elements" we mean the individual components of the part, such as, in the previous examples, an individual roller, ball-bearing or the inner or outer race of a rotary bearing, or the rotary shaft in a part comprising a shaft and tube as sub-elements.

In the preferred embodiment, an annular member is provided with one or more circumferential extending fingers at least a portion of which is in contact with the part to be monitored. Each finger is provided with piezo ceramic material or the like in order to create a cantilevered piezo electric sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the present invention be more clearly understood, an embodiment thereof will now be described by way of example with reference to the accompanying drawings, in which:-

Fig 1 is an exploded assembly showing the use of the present invention to monitor a rotary bearing; and

Fig 2 is a detailed view of an element of the present invention.

Detailed Description of the preferred embodiment

Before describing the embodiment with reference to the drawings in detail, it should be noted that certain features of the parts shown in the drawings have been distorted for reasons of clarity and the actual features are all between 0.05 and 0.25mm in depth.

Referring now to Fig 1, a standard bearing (80) has its outer diameter reduced by a small amount, typically 0.4mm, and around the outside of the reduced diameter bearing is fitted a monitoring ring (90) which is preferably made of heat treated carbon steel. The ring is selectively machined eg etched using a process such as electro-chemical machining, where a free-flowing electrolyte and high current are used to rapidly erode the target with a shaped electrode.

The electro-chemical machining creates a series of features:

Unaffected rings of material on the outer edges of the ring (10).

A number of pockets (20) between the unaffected rings (10), separated by axial rungs of unaffected material (30) the axial rings being circumferentially separated, as shown. The number of pockets will depend upon the ratio of bearing radius to width, but for convenience this description will assume 3 such pockets.

The pockets are formed on both the inner and outer surfaces of the ring to create a shelf.

The shelf portions are further machined to form a U shaped feature that passes completely through the shelf portions to form a cantilever (50) which is shown more clearly in Fig 2. The U is oriented such that the unsupported end (60) of the cantilever includes a portion of the rung-like feature (30). An alternative embodiment can provide for the formation of a dedicated sensing rib, if preferred. This is not illustrated but can be achieved simply by a change in the design of the tool.

After the formation of the ring as thus far described, piezo ceramic material is applied to one or both faces of each cantilever (50). A number of techniques are known for building up such layers, including printing, composite sol-gel spin coating and the bonding of malleable sheets formed using viscous ceramic processing. The ceramic thickness will vary to suit the particular bearing but will typically be between 25 and 100 microns.

If the ceramic is fired and poled in situ the material must either be applied to both sides or just the inner, to ensure that the shape change upon poling does not pull the ridges away from the original diameter. Poling involves the application of a high voltage at a temperature above the material's Curie point, followed by cooling with the voltage present to align the oxygen atoms within the crystal structure.

Additional features for the attachment of sensing wires to obtain the output voltage generated by the piezo-ceramic material are required but have been excluded for clarity. We believe that it would be apparent to the intended reader how such connections could be made to obtain the output voltage of the piezo-electric ceramic using sensing wires, and numerous arrangements are possible.

The assembly as described above is applied to the reduced diameter bearing by heating the assembly to no more than 60% of the Curie temperature of the ceramic and cooling the bearing to a low temperature. When the two parts equalise in temperature the touching diameters will become intimately bound together.

Once assembled the ridges on the tips (60) of the cantilevers (50) will be in intimate contact with the outer circumferential face of the bearing race (80) such that the passage of the balls or rollers within the bearing will distort this surface as they pass and cause the piezo-electric mounted on the cantilever to generate a voltage output which will rise and fall sinusoidally.

In the event of a ball or roller becoming damaged the sinusoidal motion will be accompanied by a sharp peak that indicates the scoring action of the damaged ball against the race. This peak will appear sequentially at each of the three or more sensors and will have a frequency of the rate of revolution multiplied by the number of sensors.

In the event of the outer race becoming damaged then a signal that has the frequency of the rate of revolution multiplied by the number of balls in the race, minus the rate of slip of the balls, will be created.

Because the outer race is fixed to the ring assembly, the position of the signal will be fixed, so two sensors will detect it more loudly than the others, permitting the nature of the failure to be determined.

In the event of the inner race becoming damaged then a signal with the frequency of the rate of revolution multiplied by the number of balls plus the rate of slip of the balls will be created.

The level of slip can be measured by knowing the number of balls and the true rate of rotation and comparing this to the sinusoidal output of the sensors.

The use of frequency filters and other signal processing techniques is well known and need not concern us here.

If it is not desired to qualify the nature of the failure, then in another embodiment the multiplicity of sensors can be reduced to a single part which can enclose the bulk of the circumference. Such a configuration will give an enhanced sensitivity.

In addition to use for the direct measurement of bearing conditions, the same construction can be applied to any rotating shaft to detect grating or out of balance conditions.

It is also clearly possible to reverse the points which are in intimate contact and sense against the bore of tube. Equally, if size is not a restriction, the monitoring ring could be added to any rotating member to detect imbalance.

CLAIMS:

1. A sensor for monitoring rotational parts comprising a piezo-electric element arranged to contact a part to be monitored, and to generate an electrical output signal as a result of either: rotary motion of the part; or rotary motion of one or more sub-elements of the part.

2. A sensor according to claim 1, and further comprising a plurality of piezo-electric elements each arranged to contact the part to be monitored and each arranged to generate a respective electrical output signal as a result of either: rotary motion of the part; or rotary motion of one or more sub-elements of the part.

3. A sensor according to claim 1 or claim 2, and further comprising an annular member having one or more circumferentially extending figures, said piezo-electric elements being respectively mounted on at least one major surface of said fingers such that in use the piezo-electric elements are in contact with the part to be monitored.

4. A sensor according to claim 3, wherein said one or more fingers are respectively provided with piezo-electric elements on both major surfaces of said fingers.

5. A sensor according to any of the preceding claims, wherein said part to be monitored is a rotary bearing, and said piezo-electric element contacts the outer surface of said bearing.

6. A sensor according to claim 5 when dependent upon claims 3 or 4, wherein an inner diameter of said annular member is of such a size as to fit over the outer casing of said rotary bearing so as to cause said bearing and said annular

member to become intimately bound.

7. A sensor according to any of the preceding claims, wherein said piezo-electric element(s) is formed of a piezo ceramic layer of between 25 and 100 microns (μm) in thickness.

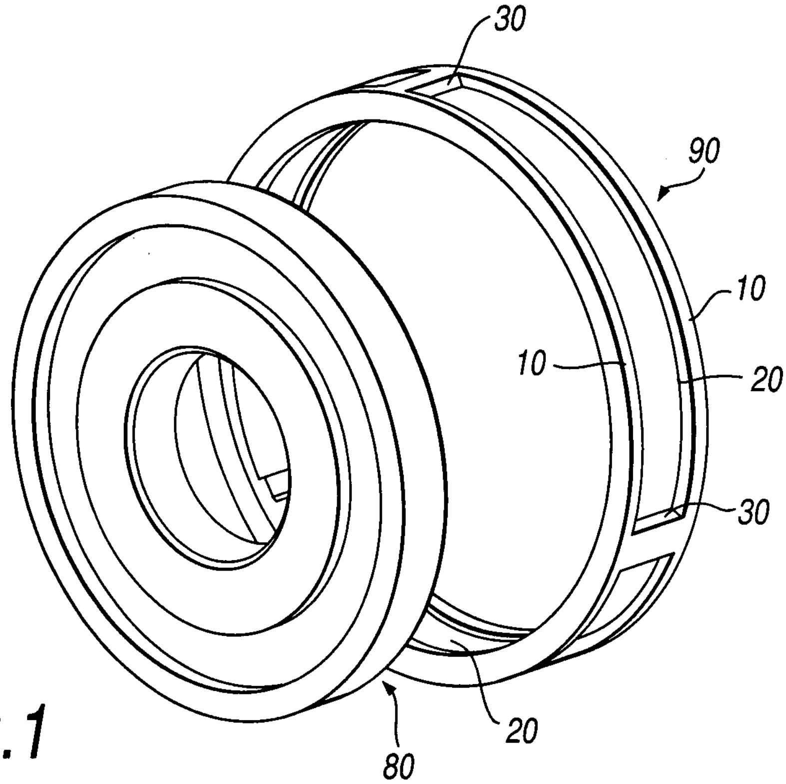


Fig.1

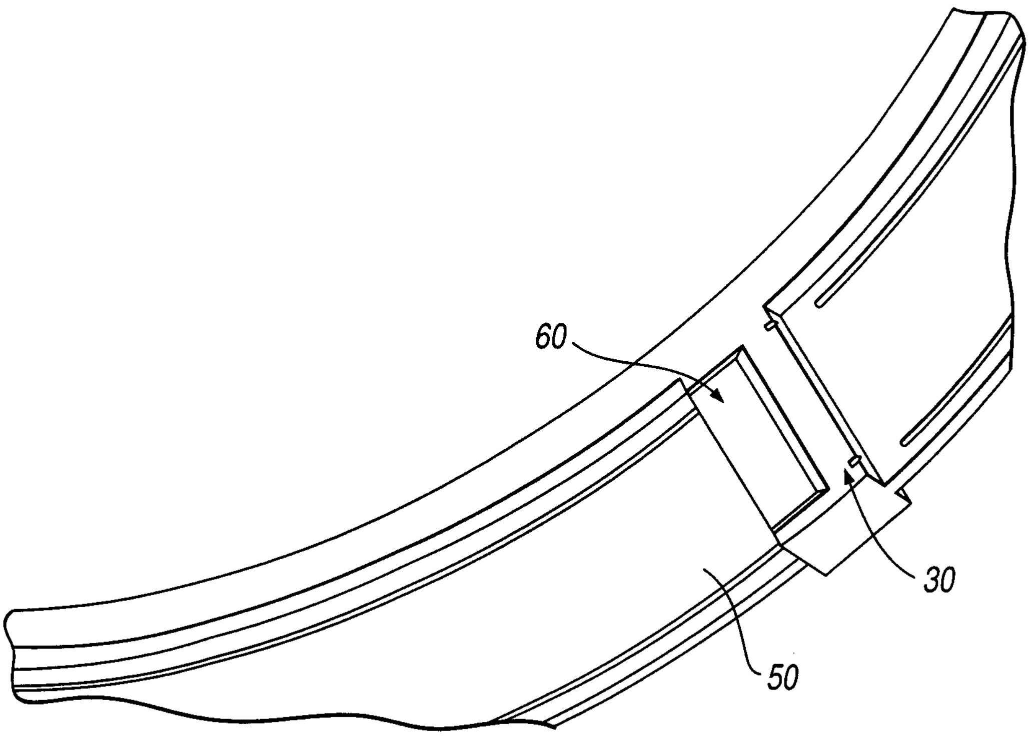


Fig.2