Fault Diagnosis of Rotating Machines using Piezoelectric Element
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Abstract:
A signal analysis technique for condition monitoring of mechanical elements with the help of vibration exciter and piezoelectric element. In this paper we study how vibration exciter with piezoelectric element help in taking vibration signature of mechanical element and converting vibration signature obtained in cps in to Hz. Experimental results show that the measured frequencies of the piezoelectric ceramic thin-plate transducers in flexural vibration under free-boundary conditions are in good agreement with the calculated results. Plotting graph and data for the signature obtained from mechanical element and again taking vibration signature of same element when vibration in machine is increased by some amount as compared to new one. The monitoring of parts takes place i.e. we have to replace the part or use for some time.

Keywords: Power oscillator, Vibration exciter, Piezoelectric element, Condition monitoring.

I. INTRODUCTION
As with the increase in technology every industry want to maximize profit with minimum production cost and for this manufacturing plant are expected to run continuously for extended hours.[1] Consequently unexpected failure of machine has become more costly than ever before and therefore conditioning monitoring of machine has gaining more importance to reduce unexpected failure of machine parts so that they can run for extended hours and increase the production of industry.[2] Many method based on vibration signal analysis have been developed. The use of vibration exciter with the help of piezoelectric element for testing mechanical elements is new approach for taking vibration signature.[3] In this paper firstly with the help of vibration exciter artificial vibration is produced and with the help of piezoelectric element noted the vibration produced and plotted graph of that vibration in Matlab® and convert it in cycle per second or Hz. Now for the monitoring of machine firstly taking signature of new machine and save them and after some time when machine part completed its age we again take signature of parts and comparing these signature with previous one and from this conclusion is made that the parts is still use in industry or we have to replace it.

II. DESIGN OF VIBRATION EXCITER
Vibration exciter system is of electrodynamics type. It essentially consists of an electro magnet around which the exciter coil is suspended. The electromagnet is supplied with a steady DC current which set up DC magnetic field. When an electric signal is applied to exciter coil, magnetic flux is created by the electromagnet, which results in the upward or downwards movement of the coil depending upon the direction of current flow in the exciter coil. If AC current is supplied, the exciter coil moves up and down with the same frequency as that of the alternating current. Thus by controlling the frequency of the current input and magnitude of current input to the exciter coil, the frequency of vibration and amplitude of vibration can be controlled. The control of the vibration exciter is done by a power Oscillator which consists of mainly four sections,

<table>
<thead>
<tr>
<th>Type</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Oscillator</td>
<td>Output wave form - sinusoidal</td>
</tr>
<tr>
<td></td>
<td>Frequency range - 1 Hz to 10 kHz in four decades</td>
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<td></td>
<td>Accuracy - ± 2% of range with harmonic distortion</td>
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<tr>
<td>Power Amplifier</td>
<td>Maximum power output - 250 W</td>
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<tr>
<td></td>
<td>Frequency response - 1 Hz to 10 kHz</td>
</tr>
<tr>
<td>Vibration Exciter</td>
<td>Peak sine force - 200 N</td>
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<td></td>
<td>Peak velocity at resonance - 1 m/s</td>
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<tr>
<td></td>
<td>Maximum displacement - 12 mm peak to peak</td>
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<tr>
<td></td>
<td>Bare table acceleration - 200m/sec2</td>
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</tbody>
</table>

The specifications of the different components are:
• Mass of moving element - 600 gms
• Power requirement - 230 V ±10%, 50Hz

Amplifier is protected against over voltage, overheating and over current.

III. PRINCIPLE OF VIBRATION EXCITER

To obtain reading from power oscillator firstly connect the power oscillator to vibration exciter. Interconnect the oscillator to amplifier; input to oscillator frequency is then set to required level using coarse and fine adjustment. Amplifier amplitude is gradually increased till the desired vibration amplitude is obtained. The vibration obtained in exciter output is in form of volt (RMS), is then again noted by the piezoelectric element by placing piezoelectric element to suitable place i.e. in the center of exciter and reading in form of volt(RMS) is taken. The reading obtained by piezoelectric element is converted in to Hz in the software utility in MATLAB®.[4]

![Figure 3. Vibration exciter](image)

In this first the power oscillator is set at 10 Hz so that it can generated signal at 10 Hz and obtained signal 10 cycle/second now with the help of placing the piezoelectric element near the vibration exciter again record the signal and converted in to Hz(cycle/second) by software utility MATLAB®. If the recorded signal and the signal obtained from piezoelectric is approximate same then we can use piezoelectric element to record signal from various rotating and nonrotating machine parts.

IV. PIEZOELECTRIC ELEMENT

The accelerometers has been manufacturing for over 40 years utilize the phenomenon of piezoelectricity. When a piezoelectric material is stressed it produces electrical charge. Combined with a seismic mass it can generate an electric charge signal proportional to vibration acceleration. The active element of accelerometers consists of a carefully selected ceramic material with excellent piezoelectric properties called Lead-ZirconateTitanate (PZT). Piezoelectric accelerometers are widely accepted as the best choice for measuring absolute vibration.[5,6]

![Figure 4. Pizo Disk](image)

The active element of an accelerometer is a piezoelectric material. Piezoelectric element work on the phenomena of piezoelectric effect in which piezoelectric substance produce electric charge when mechanical stress is applied. A compression disk looks like a capacitor with the piezoceramic material sandwiched between two electrodes. A force applied perpendicular to the disk causes a charge production and a voltage at the electrodes. One side of the piezoelectric material is connected to a rigid post at the sensor base. The so-called seismic mass is attached to the other side. When the accelerometer is subjected to vibration, a force is generated which acts on the piezoelectric element According to Newton’s Law this force is equal to the product of the acceleration and the seismic mass. By the piezoelectric effect a charge output proportional to the applied force is generated. Since the seismic mass is constant the charge output signal is proportional to the acceleration of the mass.

\[ F = m \cdot a \]
\[ \text{Where, mass} = \text{constant} \]
\[ F \propto a \]

But

Charge output \( \propto \) Force (by piezoelectric effect)

Charge output acceleration

V. EXPERIMENTATION

Firstly connect the power oscillator to vibration exciter so that exciter excite up and down and reading available in cps at a particular Hz by adjusting from oscillator. Now put piezoelectric element on exciter and other side of piezoelectric is connected by microphone jack by cable so that ultimately we connect piezoelectric element to laptop in which MATLAB® is installed. By adjusting the knob of oscillator at different frequency different value of exciter output in RMS are obtained then all these value are converted in to Hz through software utility.[7]

![Figure 5. Frequency obtained by exciter at 10 Hz](image)

![Figure 6. Frequency obtained by exciter at 20 Hz](image)
These are the different graphs that are obtained at different frequency 10Hz, 20 Hz, 40 Hz,60 Hz,80 Hz and at 100 Hz and their respective peaks at 10,20,40,60,80,100 Hz are obtained.

VI. CONCLUSION

A piezoelectric element used for condition monitoring of machine is very useful for small scale industry, because they are not able to do costly predictive maintenance. Use of piezoelectric element direct as an accelerometer shows good results. The frequency obtained by piezoelectric element firstly verified by vibration exciter. The sensitivity of this piezoelectric is also high (.02 to 100 m/s^2i.e. from 3 Hz to 100 KHz). Condition monitoring through this is predictive and proactive approach towards maintenance.

VII. REFERENCES


