Machinery Health Monitoring

ENDEVCO TECH PAPER

TP263

TRENDS IN MACHINERY PROTECTION SYSTEMS

John S. Mitchell*

During the past several years significant fundamental changes have occurred in the field of machinery protection, analysis and health monitoring. Initiated by the trend toward smaller design margins at higher power levels and speeds, reduced manning and the spiralling cost of lost production and repairs, the integrated monitoring and protection system has now become a very attractive reality. Properties of lubricating oil, including pressure, temperature, condition and reservoir level; bearing temperature, shaft speed, gas turbine exhaust temperature, compressor inlet and discharge temperature, flow and pressure ratios and wideband vibration are some of the parameters which must be measured at varying intervals, normalized and compared to limits for an accurate assessment of machinery health.

Of these parameters, vibration has been perhaps the most difficult to interpret and utilize to its full potential as a prime indicator of mechanical condition. Methods evolved to utilize vibration as a measure of machinery condition have, quite logically, concentrated on the detection and analysis of existing problems. As a result, most of the sensors, methods of analysis and continuous vibration monitoring systems in general use were selected for their reaction to common machinery malfunctions such as instability, unbalance, and misalignment.

While this approach has enabled the user to detect the vast majority of machinery problems in time to avoid damage, an occasional machinery failure still manages to slip through without warning, even on machinery protected by continuous vibration monitoring. A failure of this type, such as a shaft fracture or loss of blading, is fortunately a rare occurrence; however, it often results in severe damage requiring weeks, possibly even months of expensive downtime for repair. Since the impact of one catastrophic failure can offset the gains accrued from years of successfully detecting the more common problems, the subject of vibration protection requires still further reexamination and consideration in our view.

As an important first step, vibration analysis is gradually expanding into the higher acoustic frequencies used for years as a measure of mechanical condition by those experienced enough to relate abnormalities or changes in sound to deviations in mechanical performance. Incipient cavitation and surge, the condition of anti-friction bearings and couplings, gear performance and condition, as well as the condition of turbine and compressor blading, are some of the machinery characteristics which can be examined and evaluated with the higher frequencies. As the vibration patterns produced by these characteristics are quantified and related to specific mechanical conditions at the point of origin, the knowledge gained can be effectively applied to improve the coverage and protection of vibration monitoring systems.

---

*Manager of Technical Services, Endevco Machinery Health Monitoring Division, Rancho Viejo Road, San Juan Capistrano, CA 92675, U.S.A. Published in Diesel & Gas Turbine Progress, March 1975.

1/77

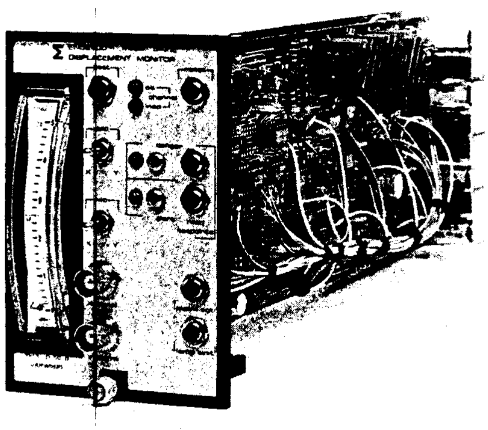

Figure 1
This dual channel monitor with self-contained meter measures true peak-to-peak shaft displacement from two sensors located on remote rotating equipment. Two adjustable thresholds, indicator lamps and contact changes are available for warning and automatic shutdown should vibration exceed the preset levels.

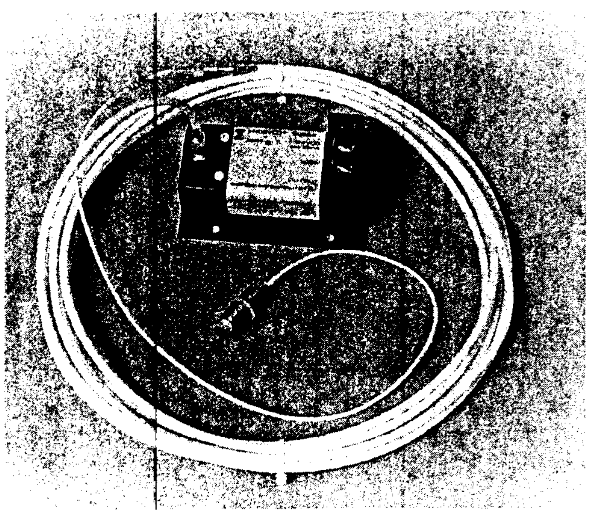

Figure 2
Endevco displacement detectors are used in combination with eddy current sensors to measure rotating shaft position and dynamic vibration.

Although shaft displacement monitoring systems have gained wide acceptance throughout industry as a prime protector of mechanical integrity, they are not completely infallible. For example, in at least three instances that I have seen, the existence of a problem was recognized from excessive casing vibration, yet its seriousness was discounted because displacement amplitudes were low and had not changed significantly. There are of course numerous opposite examples where a machine, with severe internal damage did not display conclusively abnormal casing vibration. As a result of these experiences it is becoming clear that certain characteristics are better observed on the shaft while other important characteristics are found on the casing. Thus, a comprehensive system of mechanical condition monitoring will likely employ a mixture of casing and shaft sensors in an optimum configuration for the particular machine.

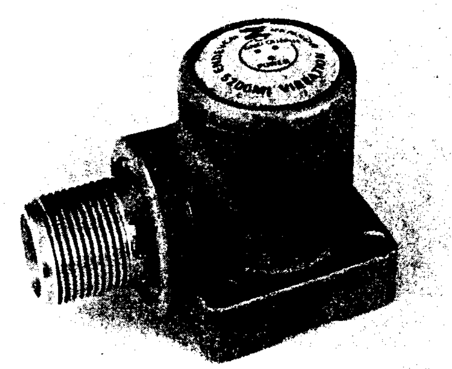

Figure 3
The Model 5200M1 is one of a line of rugged industrial sensors to be attached to rotating equipment, usually on casings. It is a piezoelectric accelerometer and can detect both low vibration frequencies as well as higher frequencies common to antifriction bearings, gears and turbine blades.

The piezoelectric accelerometer is emerging as an excellent all around seismic casing sensor for machinery protection. Its wide frequency response and dynamic range provide the capability to respond to the high frequencies mentioned earlier as well as to the low running frequencies. Attesting to its advantages, the accelerometer is replacing other types of vibration sensors for turbine engine monitoring where insensitivity to heat and shock and accessibility are vitally important considerations in addition to frequency response and dynamic range.

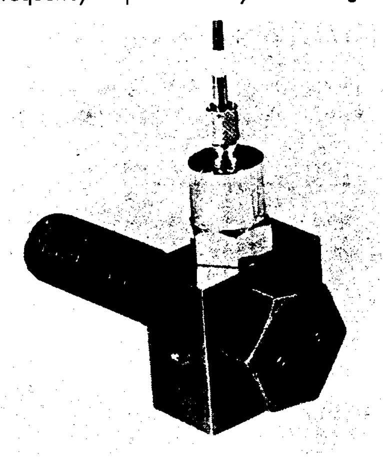

Figure 4
Typical application of heavy duty Endevco accelerometer type sensor on the casing bolt of a gas turbine engine.

With this background we can expect machinery condition monitoring and protection to evolve into modular integrated supervisory systems capable of performing both roles and employing a wide variety of variables and sensors. The modular approach is cost effective and results in substantive savings to the purchaser as well as greatly simplifying troubleshooting, since modules are replaced in their entirety rather than searching through a complex schematic for a failed component. The system should require minimum operator attention with outputs only when a deviation occurs or at timed intervals for reassurance that the system is still functioning

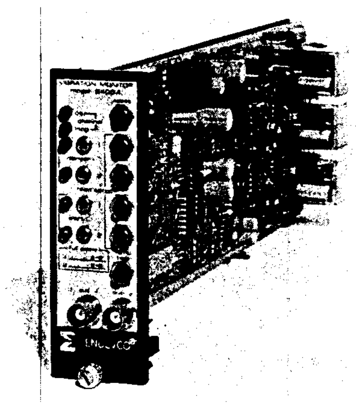

Figure 5
Endevco's Model 5400A Monitor processed vibration information from a remote sensor. It can automatically notify an operator or distant annunciator when vibration reaches "alert" or "danger" stages, and can shut down equipment automatically if it is necessary.

With the integration possible between protective and control systems, logic will undoubtedly be included to take action in the event of certain abnormalities. As an example, high frequency vibration appears to offer an excellent means for early warning of compressor surge. Under these circumstances the monitoring system could easily be programmed to assume speed or spillback control in order to prevent the onset of surge.

An ideal system must have provisions for diagnostics, either built in or possibly a central plug for attaching a portable diagnostic unit shared between several systems. The latter could be carried one step further with a central diagnostic system, hard wired to, and shared by remote machines.

Finally, and extremely important, the system must be capable of monitoring its own performance, preferably by inserting a known signal from time to time and assessing the system's response. In this fashion an operator knows the system is not only functioning but is correctly calibrated as well.

Since a supervisory system may be intimately tied to control and protection actuation functions, methods must be devised to disable portions of the system for maintenance as well as making certain it will not interrupt operations in the event of minor annoyances such as a temporary power outage. It goes without saying that an electronic supervisory system which reduced the reliability of the monitored machine due to failures within the system itself isn't going to be overwhelmingly popular.

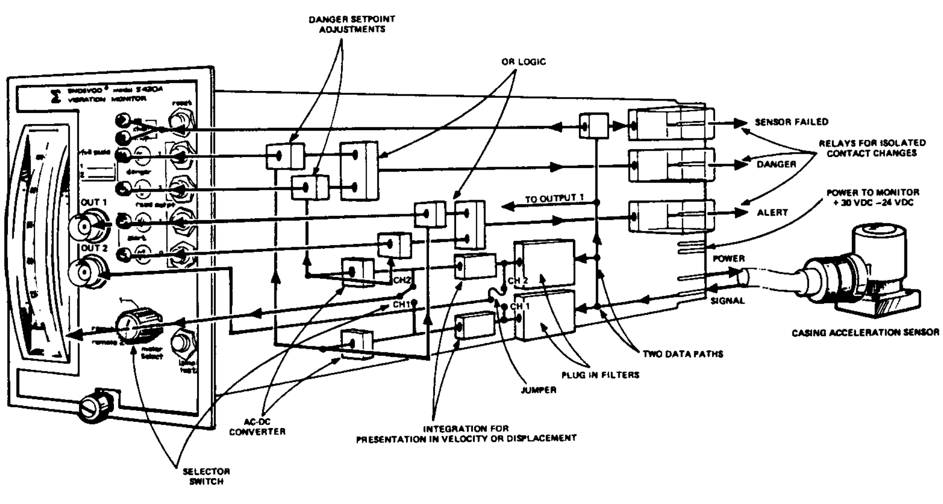

Figure 6
Endevco's Model 5420A Vibration Monitor splits the vibration signal from a single sensor into two data paths which may be fitted with filters to enable viewing a complex signal in two discrete bands or windows.

With the basic component considerations out of the way, how can the system be integrated into a functioning whole? First, of course, it is necessary to study the machine to be monitored, determine the probable malfunctions and the characteristics of each. As an example, a thrust bearing failure may be preceded by a change in pressure balance, followed by an increasing bearing load and temperature and finally metal particles in the oil and a shift in axial position. Each variable must be examined to determine its ease in measurement, accuracy as a malfunction indicator, ability to warn in time to prevent damage, and of course reliability. Generally, the variable which scores highest in all four categories should be selected as a prime indicator with the remaining acting as secondary or confirming symptoms.

Once prime and secondary symptoms have been determined, a logic ladder can be constructed calling for specific actions at certain levels of severity. For example, an automatic shutdown could be initiated when one particularly vital parameter went out of limits or, as an alternate, a primary plus one or more confirming symptoms may be required as necessary conditions for shutdown. In the latter case, automatic protection may be maintained with reasonable assurance that the system won't be triggered into unnecessary action by the failure of a single electronic component.