Where next for Condition Monitoring and Condition Based Maintenance(CBM)

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Introduction

The term Condition Monitoring has a wide variety of connotations ranging from a subjective judgement from relatively crude measurements to the use of advanced signal processing on plant data to form the basis of maintenance scheduling. It seems inevitable and certainly desirable, that the trend towards advanced signal processing will continue for high value equipment. The basic goal is clear; it is simply to gain the maximum information from the measurement data available. This begs the question of how much data is needed, a point that will be touched upon later. This paper offers a strategy for developing the topic.

Types of Analysis

In one sense, condition monitoring has always been with us. Engineers have always taken out of service machine which were exhibiting excessive noise and/or vibration or showing marked deterioration in performance. Work in the development of the subject has been aimed at the detection and diagnosis of incipient faults and the minimisation of false alarms. The increase in computing power has played an important role in recent developments.

The two classification parameters are on line/offline and statistically based or physics based. Within each of these classification is a wide variety of experience.

The simplest possible scheme would be classified as alarm triggering. Such a scheme would monitor on-line levels with a pre-set level that triggers an investigation, together with some higher level at which the machine in question would be removed from service. Most, if not all of the published standards on vibration levels are based on this type of concept. The prescribed levels for different courses of action (i.e. investigate or abort) are based on a wealth of experience, albeit unspecific.

For many years, in a process which continues today, investigators have sought refinement to this simple concept with the overall objective of accurately predicting incipient machine failure without excessive ‘false alarms’.

The assessment of the state of rotating machinery has become progressively more quantitative over the past four decades. Engineers have sought to assess rotor unbalance, bends, misalignment rub and rotor cracks as early as possible. Whilst models have played an important role in a number of cases, there are still areas of discrepancy with measured data and these to a large extent centre on the uncertainties of the supporting structure. Several groups around the world have addressed this issue by employing various techniques of System Identification. This has some important implications for future condition monitoring approaches.

Basic method of identification

The complete derivation of the method as presented in reference [1] is rather mathematical but the physical basis of the approach is straightforward. It is assumed that there exists a good mathematical model of the rotor, some less accurate description of the bearings, but little or nothing is known about the behaviour of the supporting structure. Such a scenario is common in the case of large turbo-generators whilst for smaller machine the formulation may be modified as appropriate. This is particularly easy if measurements are made of absolute shaft motion.

As shown by Smart *et al.*[1], the matrix, representing the foundation dynamic properties, is readily identified using least square techniques and similarly the unbalance vector can be established, both using data from a single rundown of the machine. It is well known that angular, or dynamic misalignment has the effect of inducing a bend into the rotor and this produces a vibrational excitation at synchronous speed which is subtly distinct from mass unbalance response. Edwards *et al.*[2] have presented a method for the identification of rotor bends.

The derivation of the static misalignment forces is a little less direct. Sinha *et al* [3] have recently reported an approach based on the identification of forces at couplings, but for large machines with rigidly coupled rotor, an alternative approach is approach based on the identification of bearing stiffnesses. Since the dynamic parameters of journal bearings is strongly influenced by the static load applied, a link can be established.

Hence it has now been established that identified values are available for the foundation parameters, the bearing loads, the state of balance and rotor bends. The static deflected shape can also now be expressed. Although this procedure might appear to some fairly complex, it is purely algorithmic and in time can be readily automated. This would allow significant information gain following each machine rundown . This sequence is readily followed:

1. Rundown automatically processed as described above
2. Estimated unbalance trended against previous values
3. Foundation parameters compared with previous values
4. Alignment changes monitored
5. If proximity probe data is available on the unit the bearing characteristics may be inferred and may be indicative of wear within the bearing.

Regarding the model and the plant data as sources of information, a judicious combination of the two will yield the maximum information about the state of the plant. This idea may be surprising to some who might argue that the plant data is 'real' whilst the model is a mere figment of imagination. This however, is not the case. It is, in the author's view, somewhat fanciful to uniquely identify all machine faults. But it is eminently feasible to yield probabilities for different types of fault. Bachscmidt *et al.* [4] have presented some work it this area but further steps are feasible with refined plant models.

References

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