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Vibration Data Screening using ExpertALERT's Average Baseline Data Methodology

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Why Average Baseline Data is Important

Experience has taught DLI that it is impractical to establish independent amplitude criteria for vibration screening. Typically, each test location produces 4,800 individual spectral peaks (800 lines of resolution x 2 spectra in high & low frequency ranges x 3 axes of data collection). Spectral amplitudes at various frequencies have different criteria and tend to vary widely for different machines. DLI's methodology for data screening is to allow the machine's actual data to determine the amplitude criteria. This methodology is implemented by creating average baseline spectral data for each Machine Identification Descriptor (MID). A unique MID is assigned to each machine in a group of machines that are identical in component model, configuration and test operating conditions. The theory is that identical machines operating at the same (or similar) speed and operating conditions, and which are in acceptable mechanical condition, produce very similar vibration signatures. A group of vibration spectra or signatures, from machines that have been determined by manual review of the data to be in relatively good condition, compose such a baseline. Multiple sets of test data are averaged together to form this baseline.

The following example will be used to clarify this concept of average baseline spectra, how DLI uses multiple sets of test data and what computations occur for each of the 800 lines of data in each spectrum. Consider a single spectral peak at 1xM (motor run speed) frequency measured at 1R (motor free end, radial direction). Assume that the user has 20 test samples in their average baseline data, collected from a several different machines of an MID tested at different times (typically monthly or quarterly). First, assume coincidentally that the peak at 1xM has an amplitude value of 105 VdB (0.1 in/sec pk) for every one of the 20 test samples. Then the average amplitude is105 VdB (0.1 in/sec pk) and the standard deviation is zero. The standard deviation is a statistically computed measure of the "scatter" of the test values. Using this example the average plus sigma (sigma = one standard deviation) = 105 + 0 = 105. On the other hand, assume that the 20 test amplitudes range from 99 VdB (0.05 in/sec pk) to 111 VdB (0.2 in/sec pk), but the average amplitude is still 105 VdB (0.1 in/sec pk). However, now the standard deviation (sigma) is 5dB due to the scatter in the data. The average plus sigma value becomes 105 + 5 = 110 VdB (0.018 in/sec pk). The more variation there is in the baseline test samples the higher the average plus sigma baseline vibration levels are relative the straight average values. The average plus sigma concept makes sense, as it is not fair to compare a current test amplitude with a straight average value if the vibration level could be significantly higher and still be in the "normal range" for that machine

ExpertALERT's Automatic Diagnostic System (ADS) module depends heavily on average baseline data in its logical process to produce a fault diagnosis. It looks at all of the significant vibration amplitudes in the spectra, at the various frequencies (in terms of rotational rate orders), and assesses them with respect to absolute amplitude as well as how that amplitude compares with the average plus sigma (one standard deviation) value.
Important note: Just because a single vibration spectral peak exceeds average plus sigma, that does not mean that there is a machine problem. Even the lowest degree of fault severity, i.e. slight, generally relies on multiple vibration peaks that exceed average plus sigma by more than 10 or 20%.

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How to Create Average Baseline Data

Note: Before creating average baseline data, ensure that all test spectra are properly order normalized!!

Consider three basic scenarios with respect to the number of machines for a given MID. The following descriptions reflect the worst cases, dealing with the first sets of data collected for each machine. As the machines are periodically tested, more data allows for easier judgment in the averaging process.

1) Three or More Machines per MID:
   Hint: If the machines are in different areas of the database tree, go to the "EXPERT SYSTEM MIDs" section near the bottom the tree and open up the appropriate MID to see all machines of the MID in one place.

   In graph mode, make use of the Add / Replace icon at the left end of the row of graph icons. After collecting a set of test data from each machine, click on the first test location of the first machine. Shift from "Replace" mode (which is the normal default setting) to "Add" mode. A little blue plus sign will appear in the icon box. Then click on the same location for each of the other machines one by one. You will then see the spectral data for all machines of that MID for that test location superimposed on top of each other. (**Hint**: Adjust the colors in your graph properties to provide good contrast among the various tests.)

   Now is the time to use judgment. There is no well-defined instruction for choosing which test samples will make good average baseline samples. Examine the superimposed spectral data, both in the low and high frequency range. Determine which machines show similar signatures, and which significantly stand out. Perform this same procedure for each test location independently. Choose which machine tests to add to the baseline. Be conservative and start with the obviously smooth running machines. Then, if necessary, run an interim ADS report on all machines of the MID. Add in more "slightly abnormal" sets of data to decrease sensitivity.

2) Two Machines per MID:
   This can be the classic case of the man with two watches not knowing what time it is. If vibration levels in general, and those at specific forcing frequencies are noticeably higher for one machine than the other, then you have to judge. Is one machine very smooth running and the other more average, or is one machine average and the other one has a problem? If you merely make one test sample the first sample in the average baseline, and not the other, there is a good chance of a repair recommendation being produced by processing data for the other machine. Using the less sensitive approach, if there is not an obvious problem with the machine with generally higher vibration levels, you may go ahead and add that test as a second average baseline sample. This situation will improve as more sets of test data are acquired and added to the baseline.

3) One Machine per MID:
   The case of a unique machine is the most difficult to manage. One must make a manual analysis judgment following the first test. If the machine is a common type, then its signatures can be judged visually versus other, similar machines of a different MID. After a while, one develops a "mental average file" for general machine types. The purpose of establishing an average baseline for each MID is that specific machine models tend to have their own idiosyncrasies and resonances, such that higher amplitudes at certain frequencies (or orders) may be normal for one model machine but not another. Remember that in this situation, a comparison to average baseline is virtually the same as comparison to previous data.

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Database Maintenance:

The above procedures should be implemented until a statistically significant sample size is achieved. For the U.S. Navy fleet of aircraft carriers, a database that DLI has been maintaining for more than 25 years, we have historically chosen a baseline sample size of 24. In other words, we have built up an average baseline for a given MID until there are 24 test samples in it, then stop adding samples. From that time forward, the baseline is a fixed entity. Theoretically, the greater the sample size, the less effect an added test sample would have on the computed values of average amplitude and standard deviation.

Average baseline data can easily be altered or reconstructed if the diagnostic results for a group of identical machines prove to be chronically overstated or understated. For example assume you have six average baseline samples for an MID. The ADS then produces several diagnoses of 'moderate gear mesh problem" in cases where you know that the fault is overstated and the absolute amplitudes of the gear mesh frequency vibration are not that high. The solution is to add one or two more test samples that include a higher gear mesh amplitude, and where the rest of the signatures look relatively "normal". The added baseline samples will serve to make the ADS less sensitive to that diagnosis. Reprocessing of the data likely will reduce the faults to "slight" or eliminate them completely.

After making significant changes to a set of average baseline data, either by adding new samples to an immature file or reconstructing an old one, it is a good idea to re-process all test data for all machines of that MID.

In ExpertALERT, the averaging tools are found in the top tool bar selection of "Expert", located between "Graphs" and "Utilities". Within this group, three of the selections are "Average current data", "Average data report" and "Erase current average data". The "Average data report" not only provides a listing of test samples in the baseline for an MID, but also allows for selective deletion of samples from the baseline. The "Erase current average data" option deletes all samples in order to completely reconstruct the baseline.