Monitoring Podded Ship Propulsion Systems

Enhancements to ship operations and maneuverability

Wave Analysis (SWAN) techniques do not suffer from the inherent limitations of vibration analysis.

Podded propulsion drives have proven their worth in the cruise line industry. Enhancements in ship operations such as greater maneuverability, space savings, low vibration levels, and greater power plant efficiency as well as reduced pollution are expanding the use of these drives on other marine craft, including military ships, ferries and tankers. But the costs of failure and the resulting unscheduled maintenance start in the millions of dollars. And the very elegance of the podded drive's sealed design makes it difficult to monitor and analyze. Many podded drive failures have been attributed to design problems, which have been addressed. But even though problems have occurred across all manufacturers, the benefits of podded propulsion have been universally judged as too great to switch back to traditional propulsion methods. Both manufacturers and operators alike need good predictive maintenance tools to ensure their mutual success.

Stress Wave Analysis (SWAN™) technology provides a solution to the problem of accurately assessing the operating health of a podded drive. It enables a ship's engineers to easily monitor and evaluate a drive's condition, scheduling maintenance at the optimal point. It also enables a manufacturer to certify the performance of a new or repaired unit, minimizing downstream liability.

A Tale Of Two Sisters

Healthy drives produce low stress wave energy, as compared to damaged machines, where energy levels are dramatically elevated in proportion to the level of damage. This makes it easy to identify the presence of adverse operating conditions, such as excessive bearing loading as a function of speed, bearing surface damage, water leakage into a shaft or bearing, and shaft or bearing damage due to lubrication problems.

SWAN technology also instantly assesses the severity of a problem. Sensors are placed at key points, based on structural paths to components of interest, such as bearings and shafts. The amount of stress wave energy detected by each sensor can be viewed real-time and is stored for historical trending.

Data from healthy drives establishes health-indicating color zones (green, yellow, and red) for tracking the operating history of a drive. Even minimally trained operators can quickly and reliably determine a drive's health by looking at the stress wave energy relative to the color zone.

Figures 1 and 2 show stress wave energy plots from sensors placed at the same point on two identical podded drives from sister ships. The drives were operated at comparable power, and the stress wave energy they produced was tracked over time. It is easy to see that the two drives exhibit different levels of stress.

The stress wave energy plot in Figure 1 shows a steady stress wave energy trend that actually decreases over the seven hour period of measurement. The dispersion of values around the trend line is relatively low, and the component appears to be in good operating health.

Figure 2, from the sister ship's drive, shows much higher levels of stress wave energy and an unmistakable upward trend over an eighteen-hour assessment period. In fact, because this data was taken right after the initial sensor installation, the amplification levels had not yet been optimized. The stress wave energy levels from the second drive were clipped at their peak values and even higher than displayed in Figure 2.

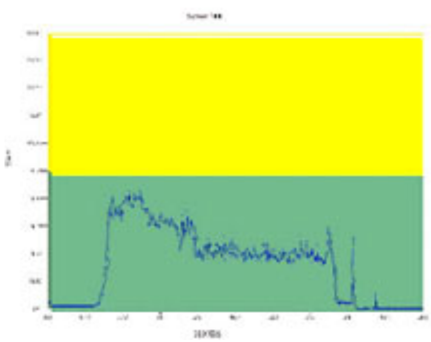

Figure 1. *Stress wave energy over 7 hour period is steady and actually decreases.*

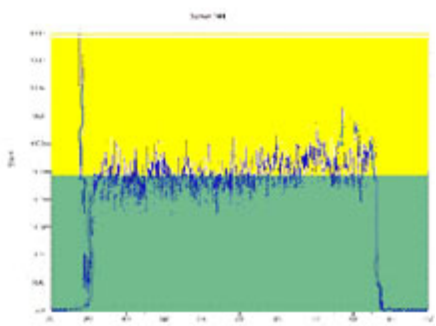

Figure 2. *Stress wave energy on a sister ship, tracked over an 18 hour period is erratic and exhibits an upward trend.*

The higher levels of stress wave energy in Figure 2 are only part of the story. While the plot shows that the drive is clearly less healthy than the one in Figure 1, it is still operating at acceptable levels of stress. Stress Wave Operating Histories, once plotted against health-indicating color zones, allow a ship's engineers to monitor drive health and accurately predict when it will reach the red zone, the point where catastrophic failure is imminent. Maintenance can then be scheduled at the optimum point, before the occurrence of failure or secondary damage to other components.

Assessing The Problem

The initial information from the data indicates that a problem is present in the sister ship's podded drive. SWAN technology provides additional tools that isolate the location of the problem and identify the cause-all without opening up or inspecting the drive. Figure 3 shows a Time-Waveform plot from the same sensor as viewed in Figure 1. The plot shows steady, consistent performance, with no significant impacting.

Stress Wave Spectral Analysis is ideal for isolating damage to dynamic components, thus pinpointing the damage location. Figure 5 shows a Spectral Analysis taken from the drive on the first ship. A flat spectrum and low background noise verify that no significant impacting is occurring.

Contrast this to the Spectral Analysis in Figure 6, taken from the sister ship. Major spectral lines at 180, 313, 360, and 626 Hz, confirm repetitive non-synchronous shock events that are unmistakable signs of bearing damage.

Stress Wave Energy as a Function of Speed
SWAN data can be readily correlated with other drive information as part of a ship's maintenance program. Figure 7 on the last page shows information from a ship's run log. We selected the area in green to analyze how the pod performed at various speeds.

Figure 8 shows that SWE levels increased dramatically and began behaving erratically as the ship cruised at 125 RPM. Once it accelerated beyond that point, levels settled down to normal as the speed was increased and held at 130 RPM.

This type of analysis enables manufacturers to identify design changes that will enhance the lifespan of their pods and reduce the lifetime dry-docking requirements for the unit. Ship's engineers can identify specific performance and tuning problems that can be addressed during maintenance and adjust ship's operations, if necessary, to accommodate specific problems.

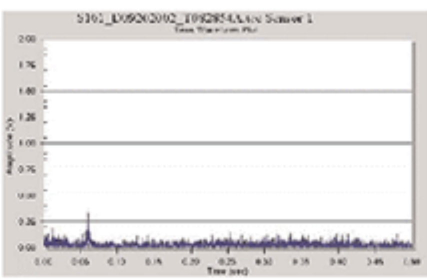

Figure 3. *Time-Waveform plot of a healthy component.*

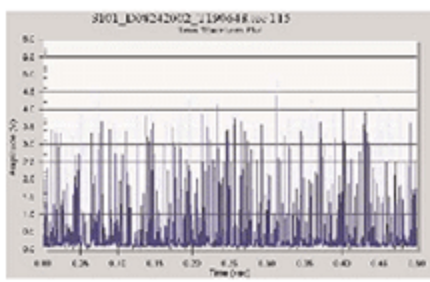

Figure 4. *Time-Waveform plot of identical drive in sister ship shows significant impacting.*

Benefits of the Predictive Maintenance Paradigm

SWAN identifies damage in the failure process earlier than any other technology. This enables ship's engineers to:

- Eliminate unscheduled dry-docking or underwater bearing and gear related maintenance activities, keeping ships on their scheduled itineraries
- Schedule maintenance at the optimum point, extending time between required dry-docking
- Eliminate secondary damage and extend component service life, reducing component inventories and consumption rates

SWAN's easy to use analysis tools offer continuous monitoring of the health of podded drives, providing:

- Reduction in the number of repair activities, even during normal dry-docking, that are required to assess the mechanical condition of a drive

SWAN technology provides additional important benefits for the manufacturers of podded drives:

- Effective design and reliability testing, identifying component and manufacturing defects
- Confirms machinery performance level during commissioning
- Reduces the effect of infant mortality issues and the overall financial exposure during the warranty term

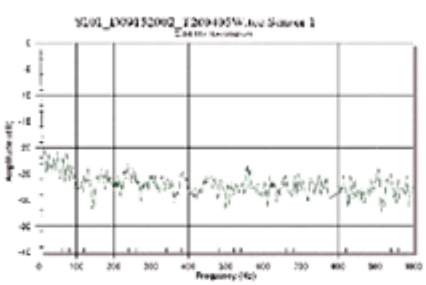

Figure 5. *Spectral Analysis ~ Healthy / low level, no significant peaks with harmonics*

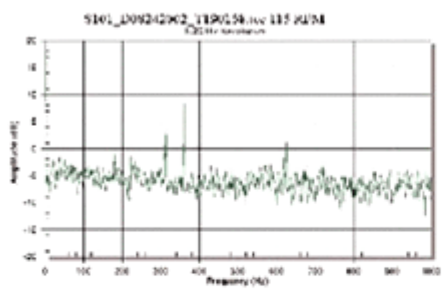

Figure 6. *Spectral Analysis ~ Exhibits the presence of several repetitive non-synchronous shock events - unmistakable evidence of bearing damage*

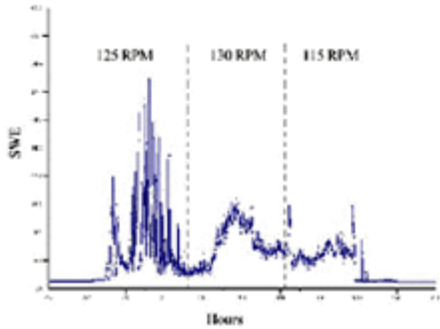

Figure 7. *Ship's run log, highlighting time for SWE analysis.*

Figure 8. *Comparison of Stress Wave Energy to run log shows that SWE increases dramatically and erratically at 125 RPM, then settles to normal and steady as speed increases to 130 RPM*

Conclusions

SWAN prevents the unexpected failure of podded propulsion drive components. When the red zone is reached on a Stress Wave Operating History chart, the drive should be pulled from service to prevent secondary damage or catastrophic failure. It is easy to project how much time it will take to reach red.

SWAN also eliminates false alarms. At least a 500% growth in signal strength is required to reach the red zone threshold. When this occurs, without question an undesirable condition has developed in the drive. When it is pulled from service, it will show clear signs of wear or physical damage.

SWAN technology provides ship's engineers with timely, accurate assessment of the health of their propulsion systems. Unlike vibration analysis, SWAN tools can accurately detect even slight shock and friction events inside a drive, bringing previously inaccessible components under the control of true predictive maintenance.

SWAN tools are powerful and sophisticated in their diagnostic capabilities; however, they are simple enough even for the most junior-level operator to use. As little as one or two days training is all that is required, as opposed to the weeks and months of initial and recurring training that are required by other condition monitoring technologies.

SWAN technology is available in several different product packages, depending upon a company's individual needs. The examples in this document were developed using the SWANguard system.

SWAN technology reduces a company's operating costs and improves its return on important assets.

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