Enhanced paper-machine runnability utilizing an on-line efficiency system

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On-line efficiency systems are powerful tools for monitoring machine performance, analyzing problems, and improving product quality.

Businesses use resources to transform inputs (raw materials, information, people) into outputs (products or services). Customers purchase outputs that meet their needs. Any company or business can be represented as a transformation system, illustrated in **Fig. 1**. For every transformation system, there is a mode of operation that produces the greatest value at the lowest cost. Any phenomenon during the transformation process that reduces value or increases the cost of delivering value is called variance. Generally, the company that controls variance most effectively will enjoy a competitive advantage.

The concept of the transformation process can readily be applied to a paper machine, where raw materials are transformed into a product as they advance from the headbox to the reel. The transformation process that takes place on the paper machine can be optimized through the use of an on-line efficiency system. **Figure 2** illustrates the areas on the paper machine that can benefit from the application of an efficiency system.

Efficiency systems provide precise information regarding variance, which is helpful in preventing or minimizing the mechanical and process disturbances that manifest themselves as speed limitations, broke, or poor sheet quality. This paper outlines efficiency-system capabilities in controlling variance and cites specific examples related to improved runnability and product quality.

Overview

An efficiency system consists of permanently installed piezoelectric pressure transducers, accelerometers, and optical sensors capable of measuring rapid process variations. Signals from these units are relayed to a computer that relates the measured variation to variation in paper quality. Information about basis weight and other quality parameters (moisture content, gloss, formation, opacity) is obtained from the paper machine's gauging system. **Figure 3** shows the types of sensors used on a paper-machine efficiency system. Signals from the sensors are converted from analog to digital so that they can be interpreted by the system's software. Selected paper-machine components are continually and automatically analyzed, with the results displayed for operating personnel.

Distributed control systems (DCS) in modern paper mills typically receive data from 1000 locations and are capable of sampling all 1000 points in one second. An efficiency system monitors fewer locations but samples each point several thousand times per second. It takes just a few seconds to gather several hundreds of thousands of samples. In the 0.1-100-Hz frequency range, rapid variations in quality cannot be eliminated by the control algorithms of the paper machine. An efficiency system, however, uses a technique known as synchronous time averaging (STA) to analyze these hundreds of thousands of samples. This makes it possible to pinpoint the individual contribution of a rotating paper-machine component (fan pump, roll, felt) and correlate its observed variance with signals from the gauging system that measures paper quality. The performance of a press felt can be monitored to determine precisely when it should be replaced. Long-term or immediate maintenance problems also can be identified through continuous surveillance of the paper machine.

Main menu

Figure 4 depicts the main menu or overview page for an efficiency system. The menu will vary slightly, depending on the product being manufactured (coated papers, tissue, board). The various paper-machine areas can be accessed simply by selecting the appropriate menu box. Typically, histories are located on the left side of the display, and the STA measurements by machine section are located in the center. The felt, roll, and nip analyses are located on the right side of the main menu and display the variance contribution of each component in a bar chart or graphic format. When the system determines that the variance at a particular machine area exceeds preset limits, an alarm box is highlighted in the top right corner.

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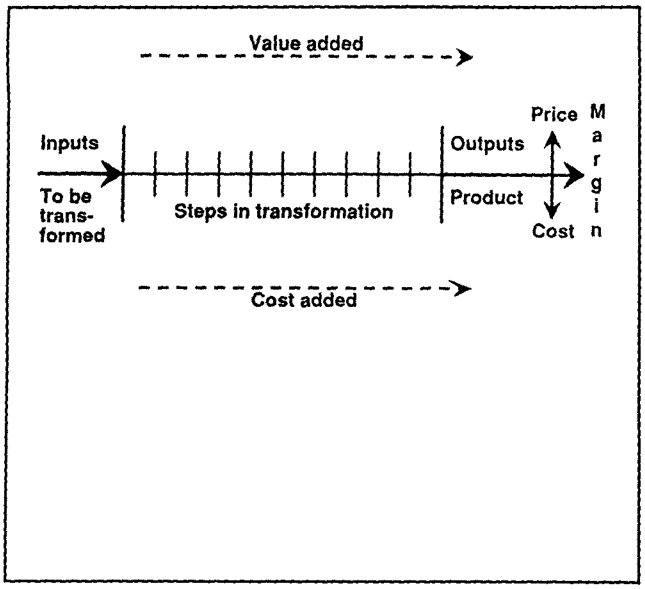
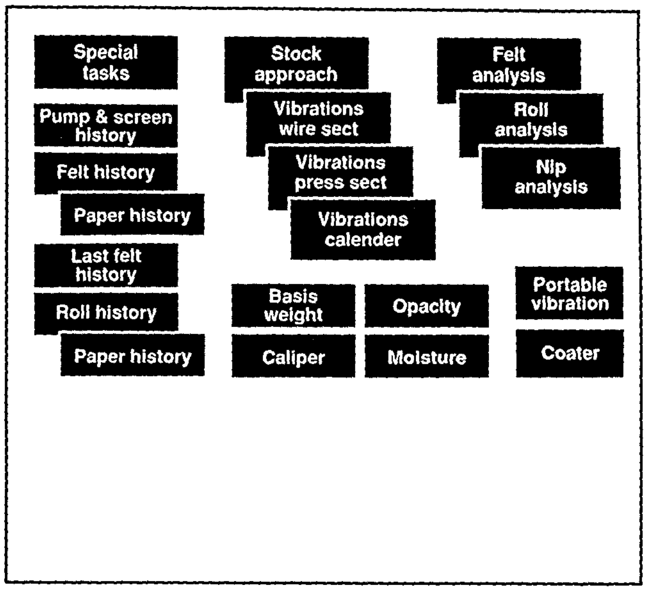
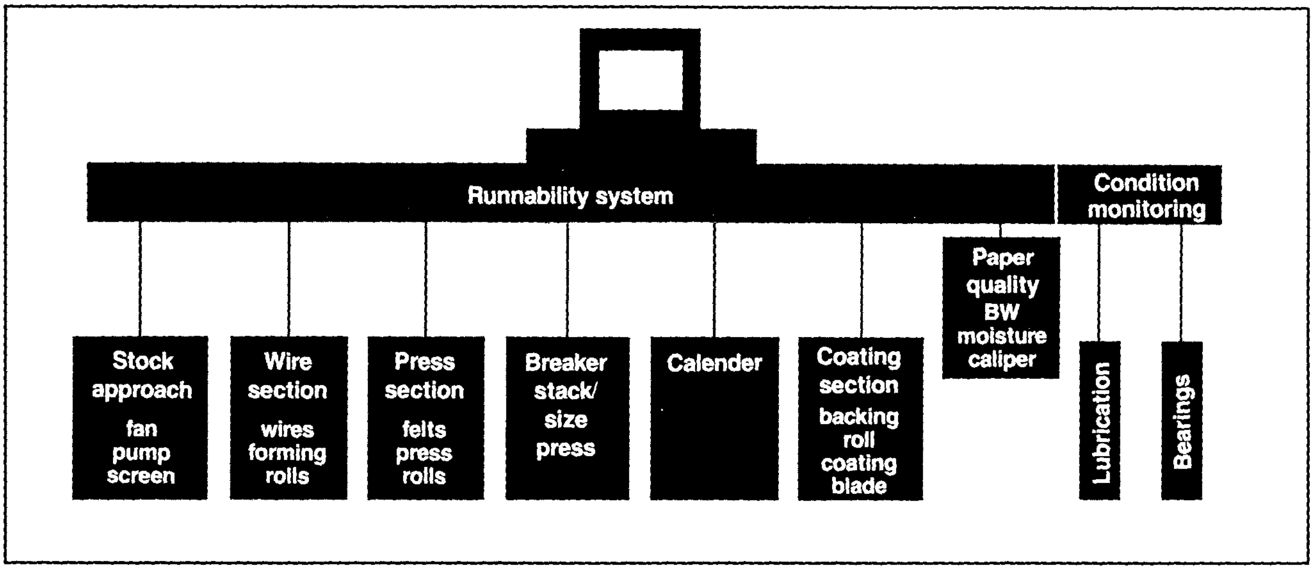
1. Transformation process



4. Main menu



2. Paper-machine operations monitored by an efficiency system



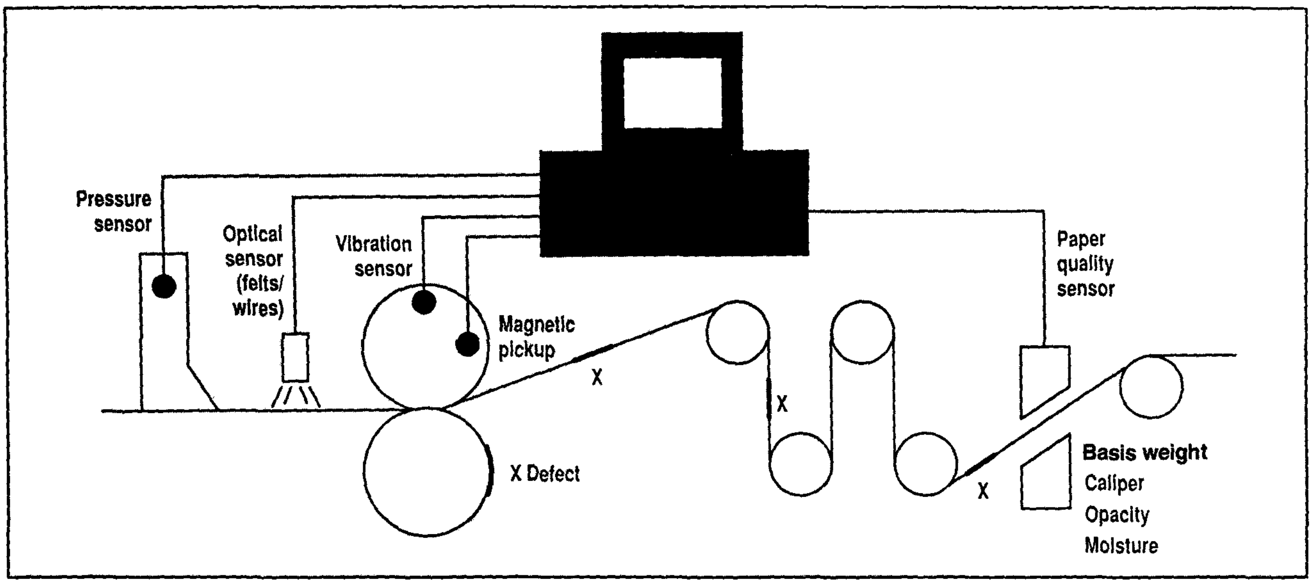
Former and press section

The efficiency system monitors vibration of machine elements, adjusting sampling rates and filters to identify specific mechanical problems such as roll imbalance, misalignment, corrugations, worn bearings or gears, and drive conditions. **Figure 5** is an analysis of a first-press suction roll that was evaluated at 10 Hz, 100 Hz, and 1000 Hz. The left polar graph suggests a cover deformation problem. The center polar graph indicates a cover delamination problem. While the right polar graph does not indicate a gear problem, it is apparent that the gear-mesh frequency is superimposed over the cover problem when compared with the center polar graph. The roll was monitored very carefully, since a spare roll was unavailable.

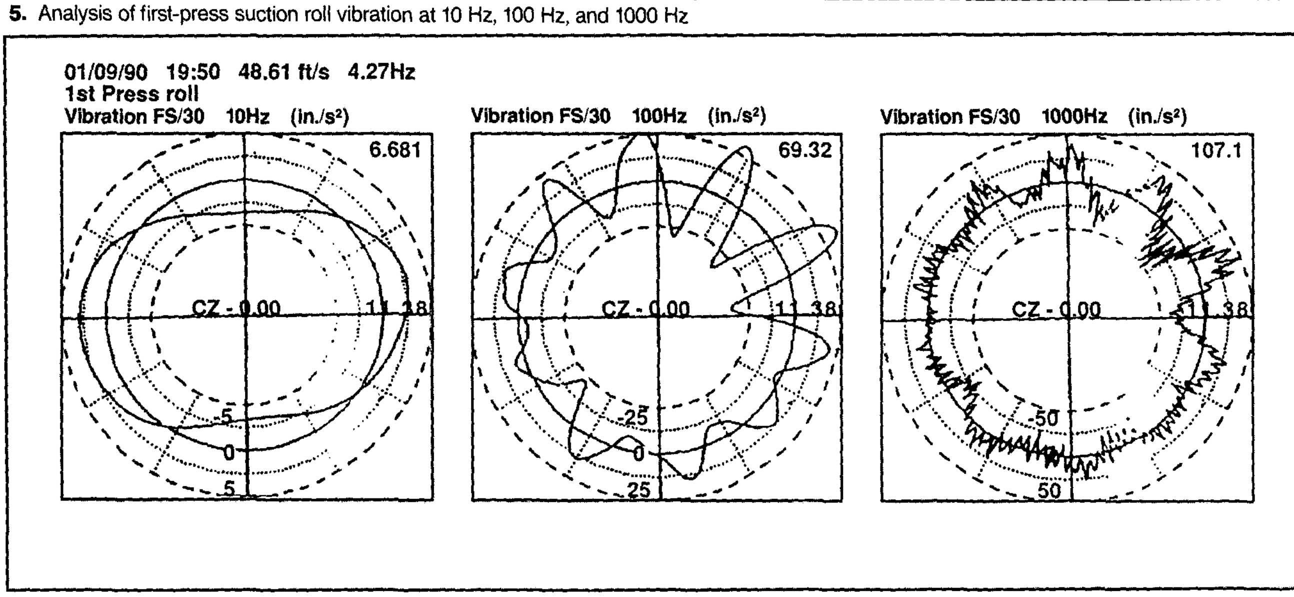
Figure 6 is an analysis of a breast roll. In this case, the amplitude of the vibration on the breast roll was not considered excessive. However, it was enough to cause variation in the sheet's basis weight and moisture content. Upon further inspection, it was determined that this roll had a plugging problem, which created a pumping action between the roll and wire, causing fluctuation in basis weight and moisture. The correlation between sheet moisture and breast-roll vibration is apparent in the synchronized spectra for moisture and the breast roll (front side and back side) in Fig. 6. The mill stayed on top of the plugging problem by monitoring variations in sheet moisture and basis weight.

Many paper-machine runnability problems are related to more than one machine component. For example, nonuniformity in press felts can excite vibration in a nip at the natural or resonant frequency. A press roll excited in this way can eventually corrugate and, in turn, bar the felt. Improved felt design may reduce the problem.

3. Sensors on paper-machine efficiency system



5. Analysis of first-press suction roll vibration at 10 Hz, 100 Hz, and 1000 Hz



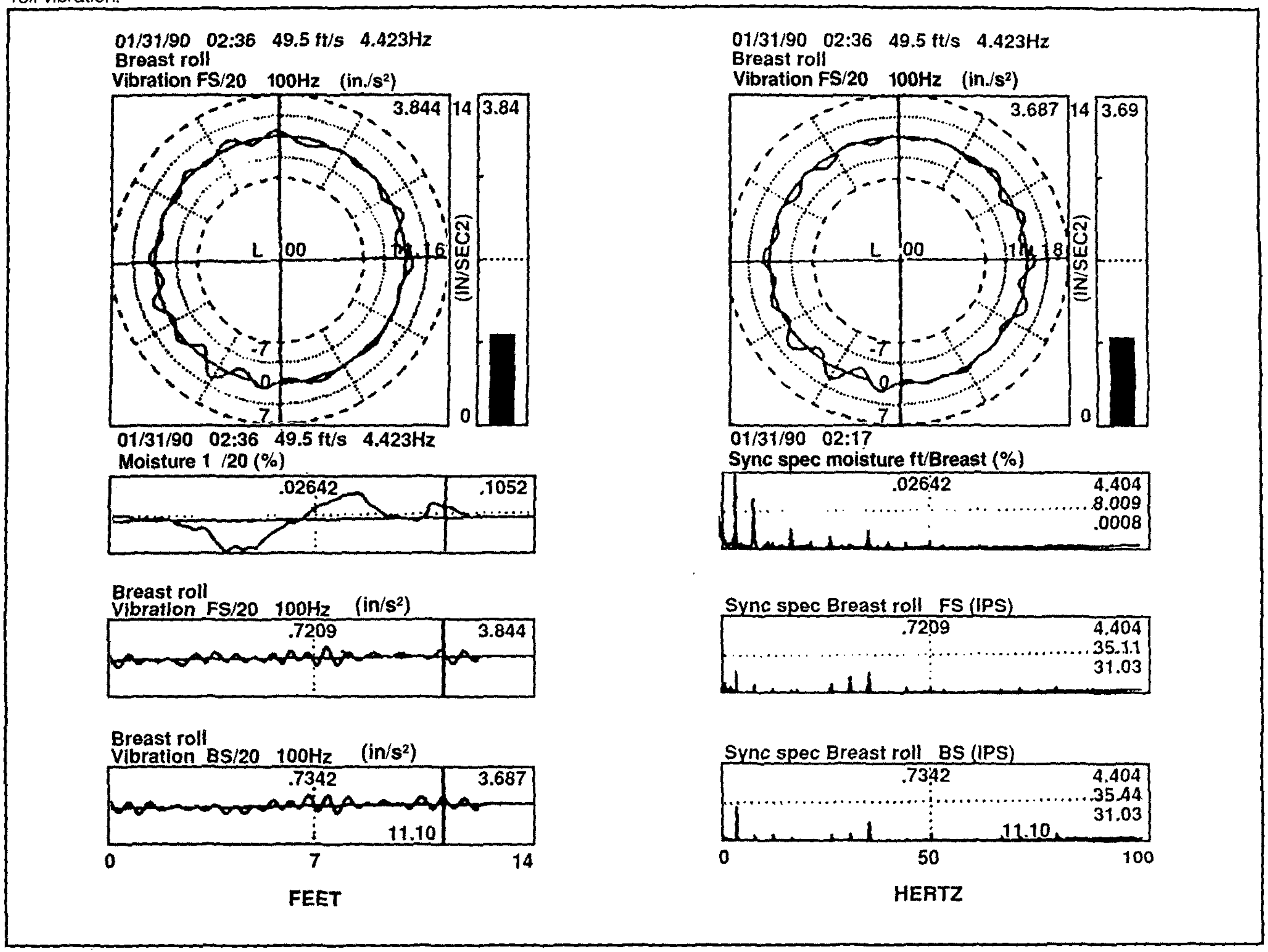
However, if a severe resonance problem exists, the physical system must be understood and modified. Press-section speed trials provide a great deal of information regarding the resonant characteristics of the machine. Results for speed trials, illustrated in **Fig. 7**, are used to identify operating speeds that will reduce vibration levels. The results also can suggest modifications to the press loading, crowns, covers, and framework.

Stock approach

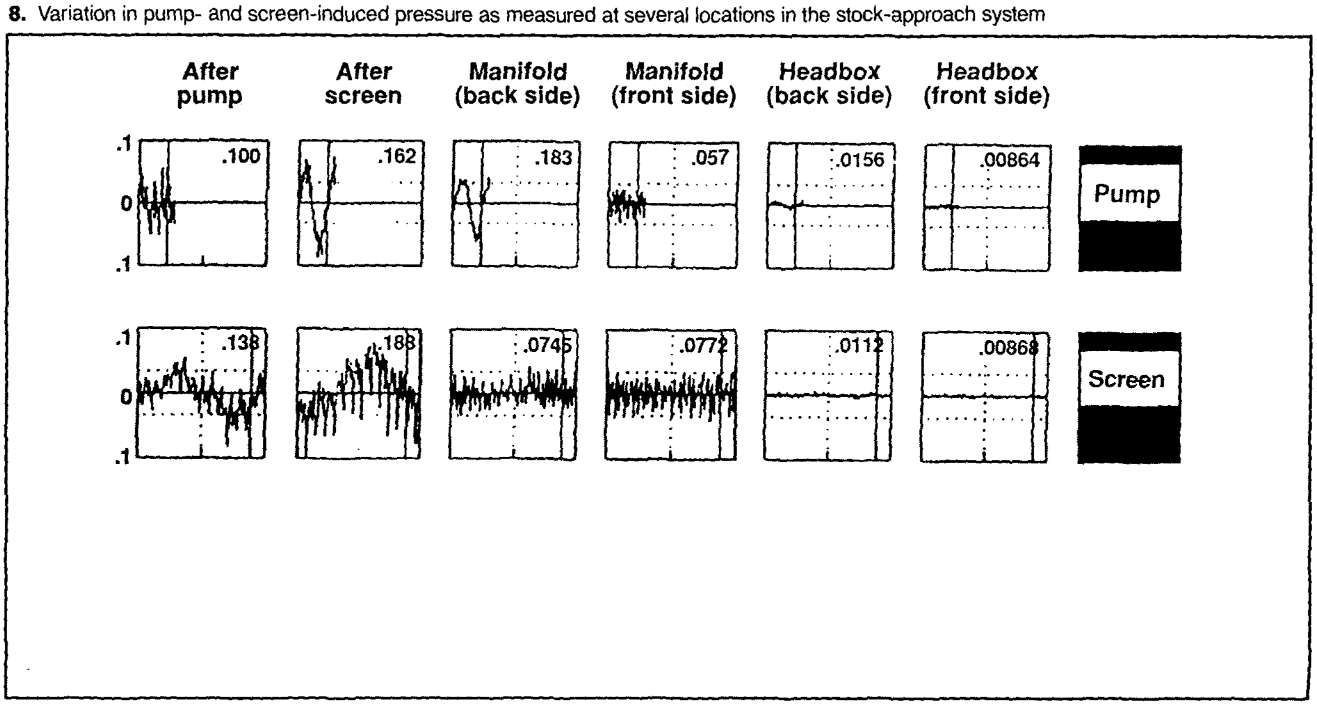
STA measurements for the stock-approach system are displayed in a different format than that used in other machine areas. Sensors are placed at several locations within the stock-approach system to measure the pressure variation that occurs with each rotation of a fan pump or screen. **Figure 8** shows pump- and screen-induced pressure variations as they travel through the stock-approach system. The locations of the pressure sensors are listed horizontally across the top of Fig. 8. The vertical line in each box indicates the end of one rotation. Mechanical problems such as improper foil gap in a screen will induce pressure variations at the foil frequency. This pulse can travel through the approach system and create a basis-weight variation in the sheet at that frequency. In one case, it was determined precisely that a 2 × fan pump speed had a direct effect on pressure pulsations. An attenuator was installed to eliminate the 2 × variation. **Figure 9** shows the results of the attenuator when it is on (shaded) and off.

The stock-approach analysis displays the pressure variations for the fan pump and screen and their effect on paper quality. The correlation between pressure variation after the screen and variation in basis weight is apparent in **Fig. 10**.

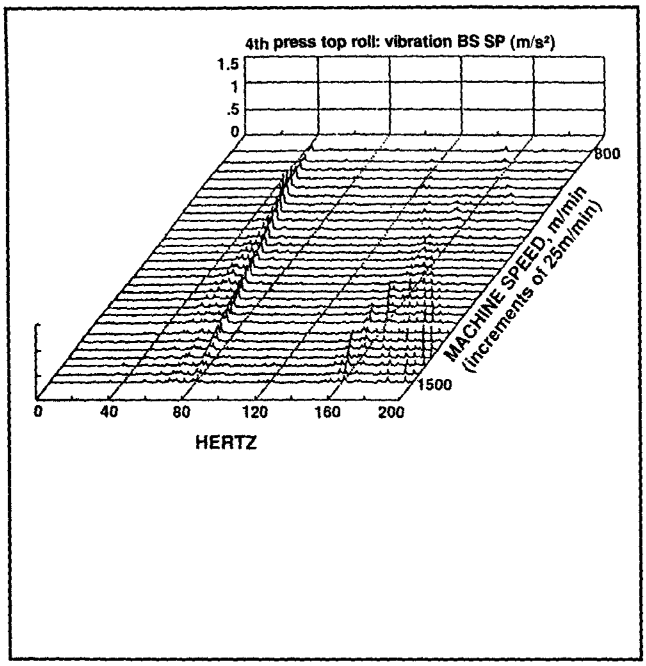
6. Analysis of breast roll. The two polar graphs represent vibration on the front side and back side of the breast roll. The graphs on the lower left depict amplitude over one cycle for sheet moisture as well as vibration on the front and back sides of the roll. (The end of the cycle is marked by a vertical line.) The graphs on the lower right are the associated STA spectra for moisture, front-side roll vibration, and back-side roll vibration.



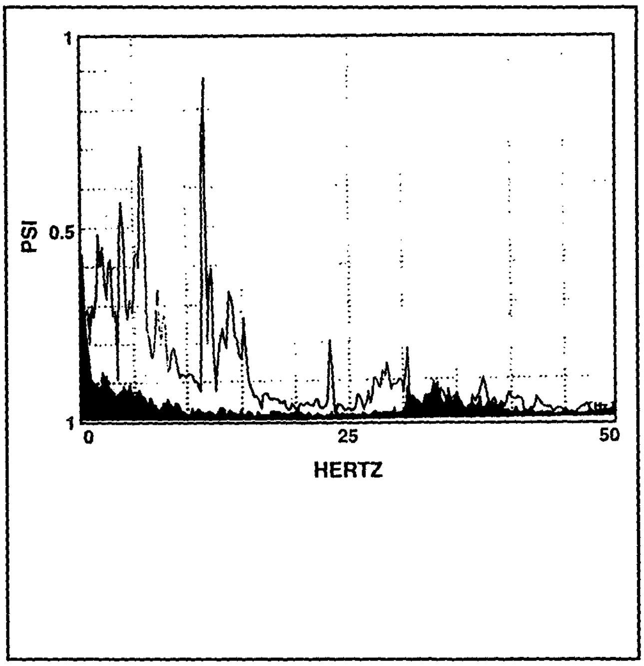
8. Variation in pump- and screen-induced pressure as measured at several locations in the stock-approach system



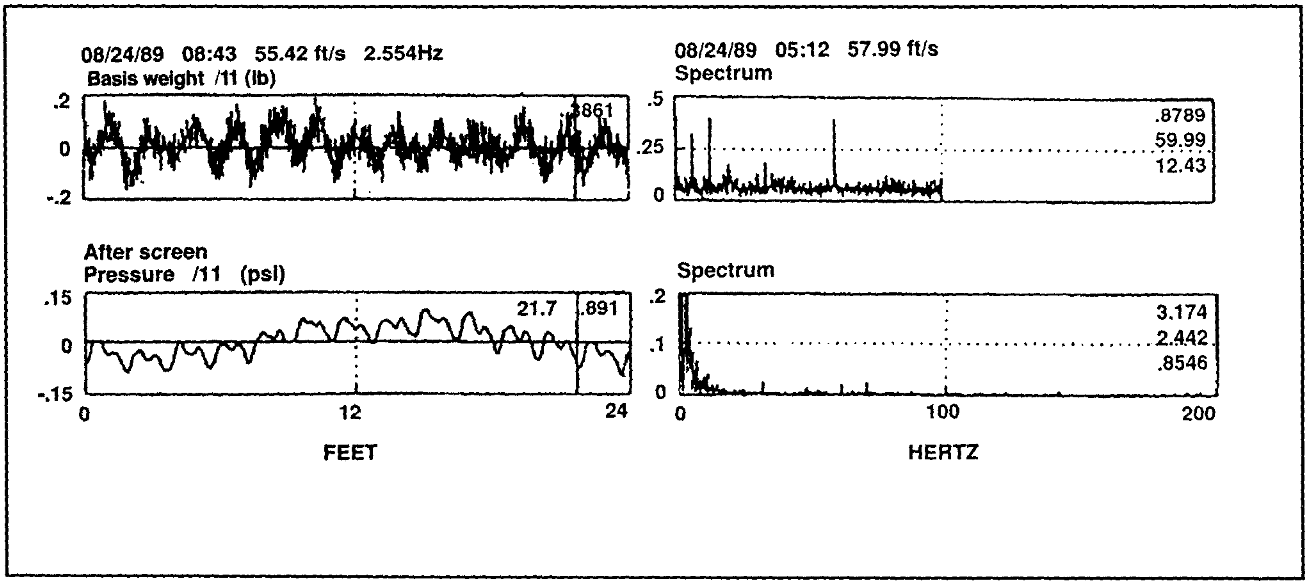
7. Speed trials showing frequency and amplitude of vibration on fourth-press top roll at machine speeds ranging from 800 m/min to 1500 m/min



9. Variation in pressure pulsation before and after installation of attenuator (Shaded area represents pulsation with attenuator active.)



10. Correlation between variations in pressure (after screen) and sheet basis weight



Felt analysis

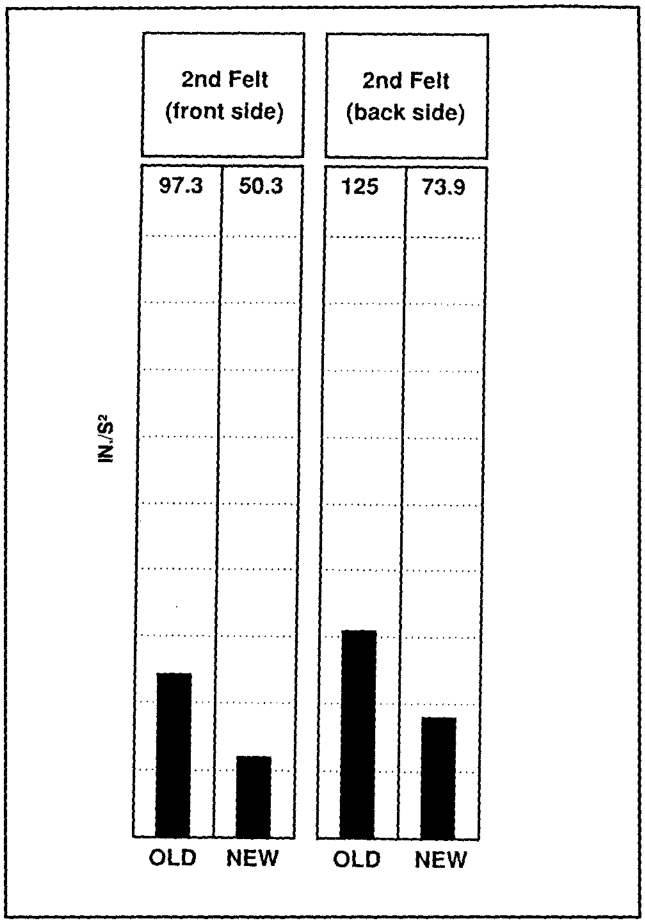
The ability to monitor felt and wire performance is another application for an efficiency system. **Figure 11** shows the vibration levels for the front and back sides of a felt. Armed with this visual reference, the machine tender can adjust the stretch and guide rolls and then update the felt analysis. The new vibration levels for the front and back sides are displayed in a bar format. The operator can tell immediately whether the adjustments increased or decreased felt vibration.

The felt trade line triggers an optical sensor once per revolution, and STA makes it possible to evaluate the condition of the felt. **Figure 12** shows felt vibration before and after adjustment. Vibration was reduced by more than 40% following the adjustment.

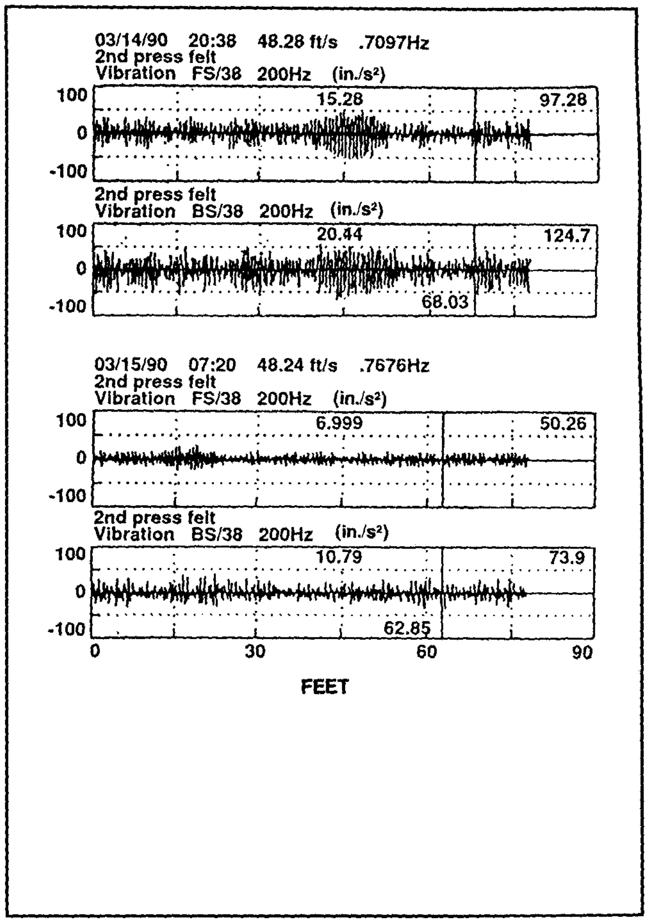
Nip analysis

The display for nip analysis shows the effect of each nip component on nip vibration and paper properties, as seen in **Fig. 13**. Individual and overall contributions for vibration are shown for the front and back sides. The information is displayed as a bar chart showing peak-to-peak (PTP) contributions of each component based on STA. Limits are set for each of the components to help the operator monitor the variance that occurs.

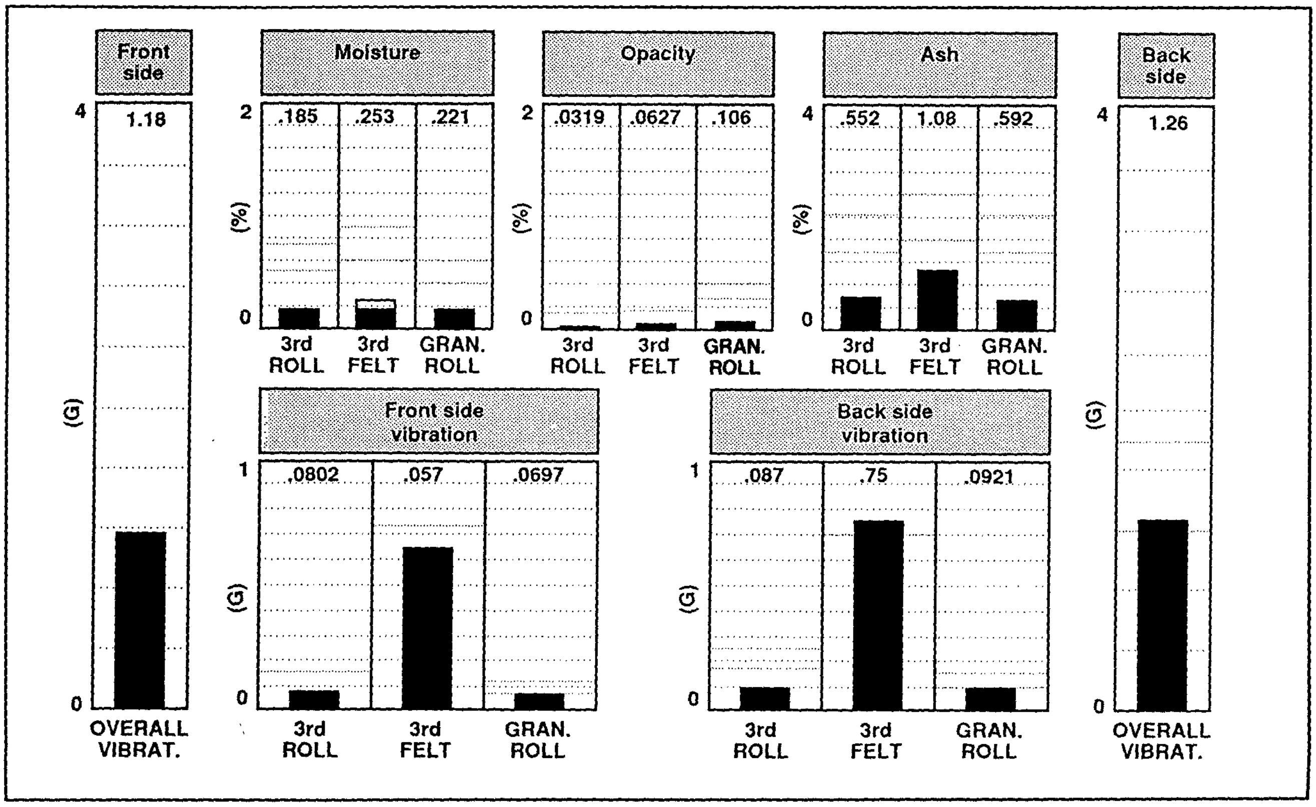
11. Bar chart showing felt vibration before and after adjustment of stretch and guide rolls



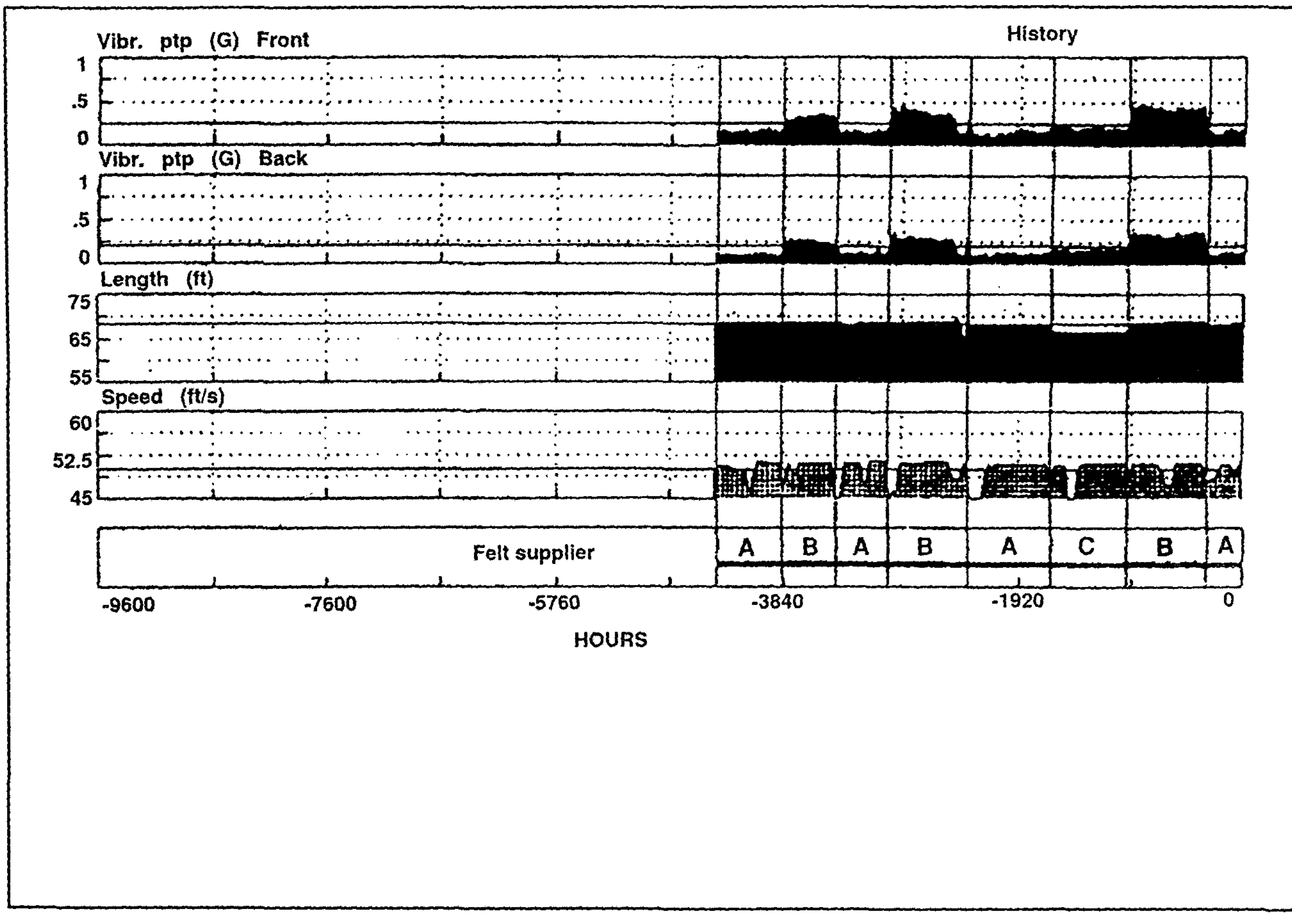
12. Vibration in front and back sides of felt before and after adjustment



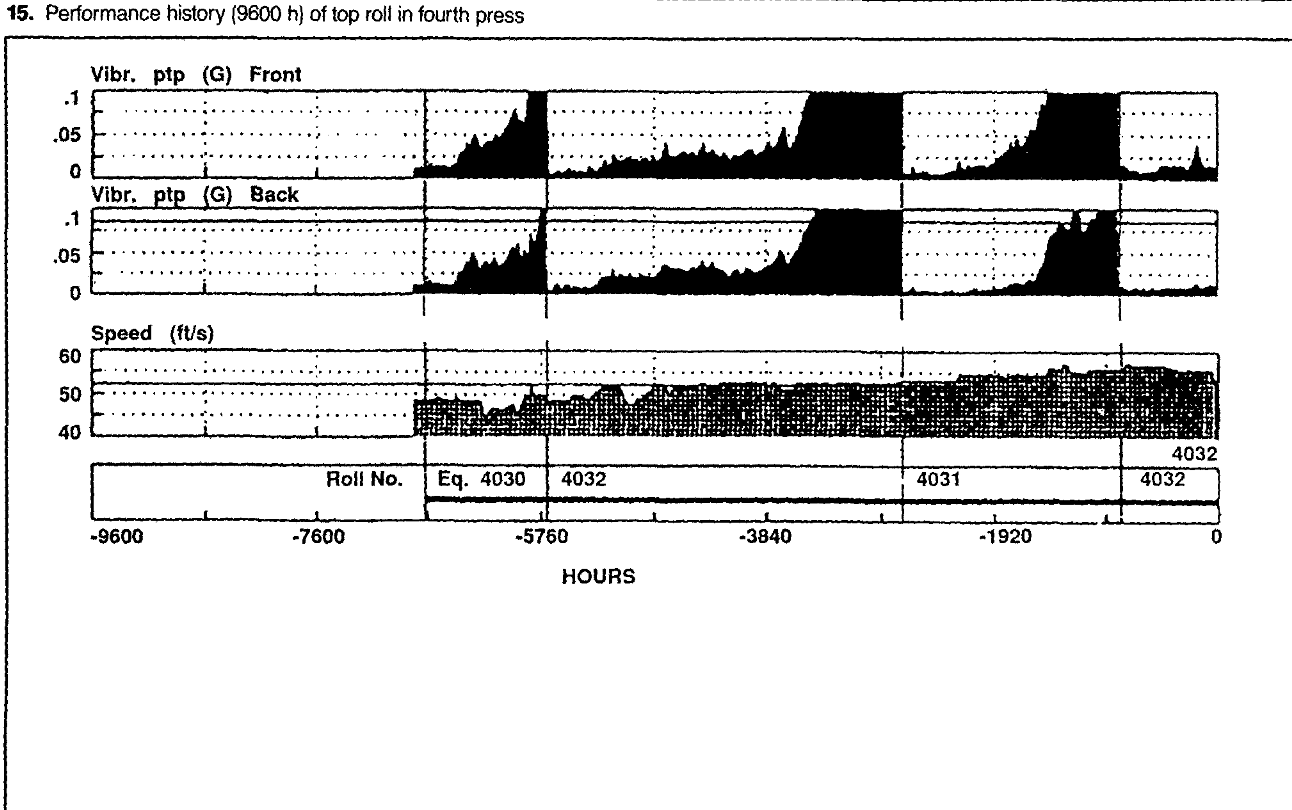
13. Operator display for results of nip analysis. The analysis presented here is for a third nip.



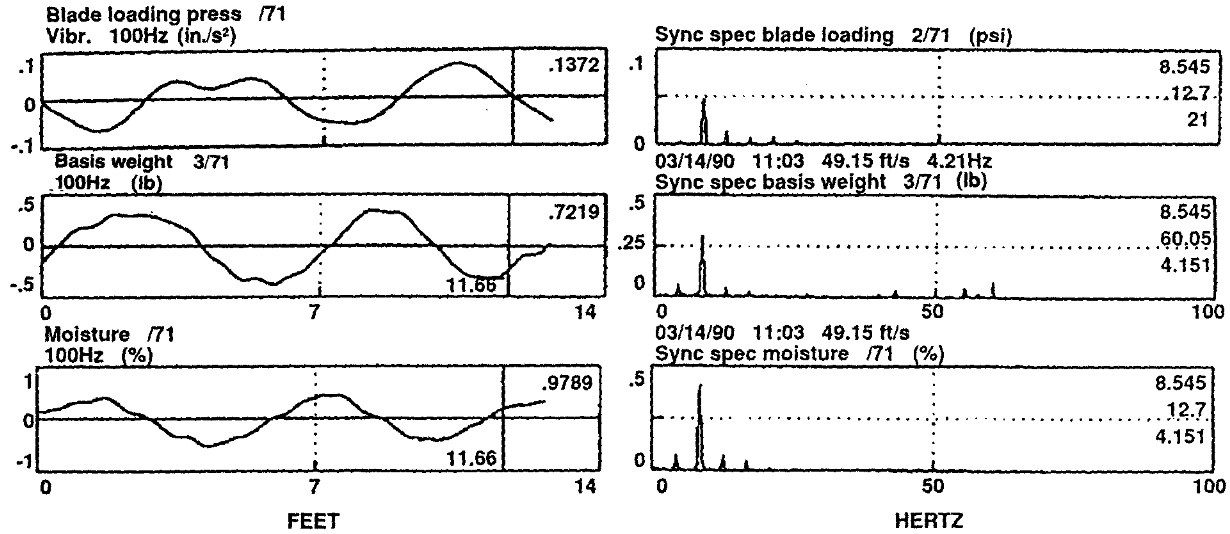
14. Performance history (9600 h) of bottom felt



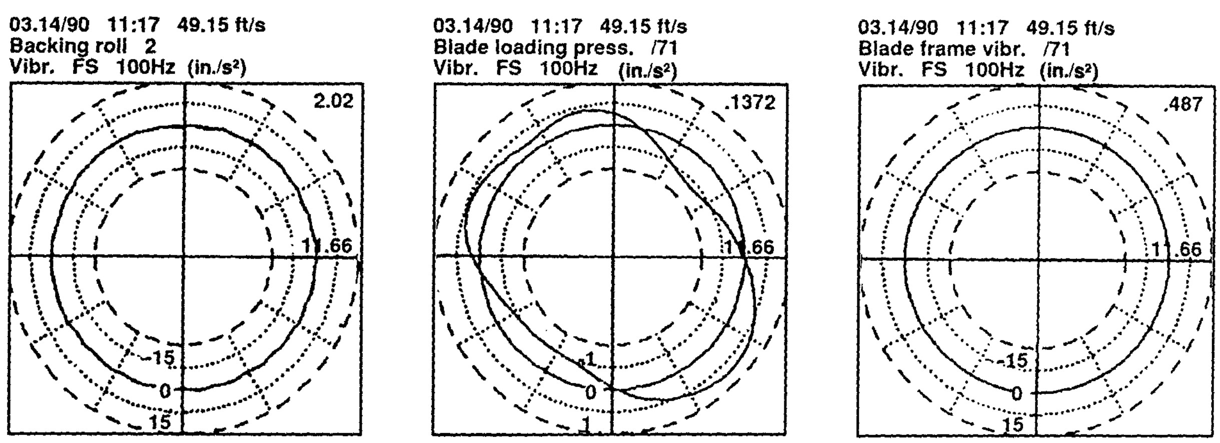
15. Performance history (9600 h) of top roll in fourth press



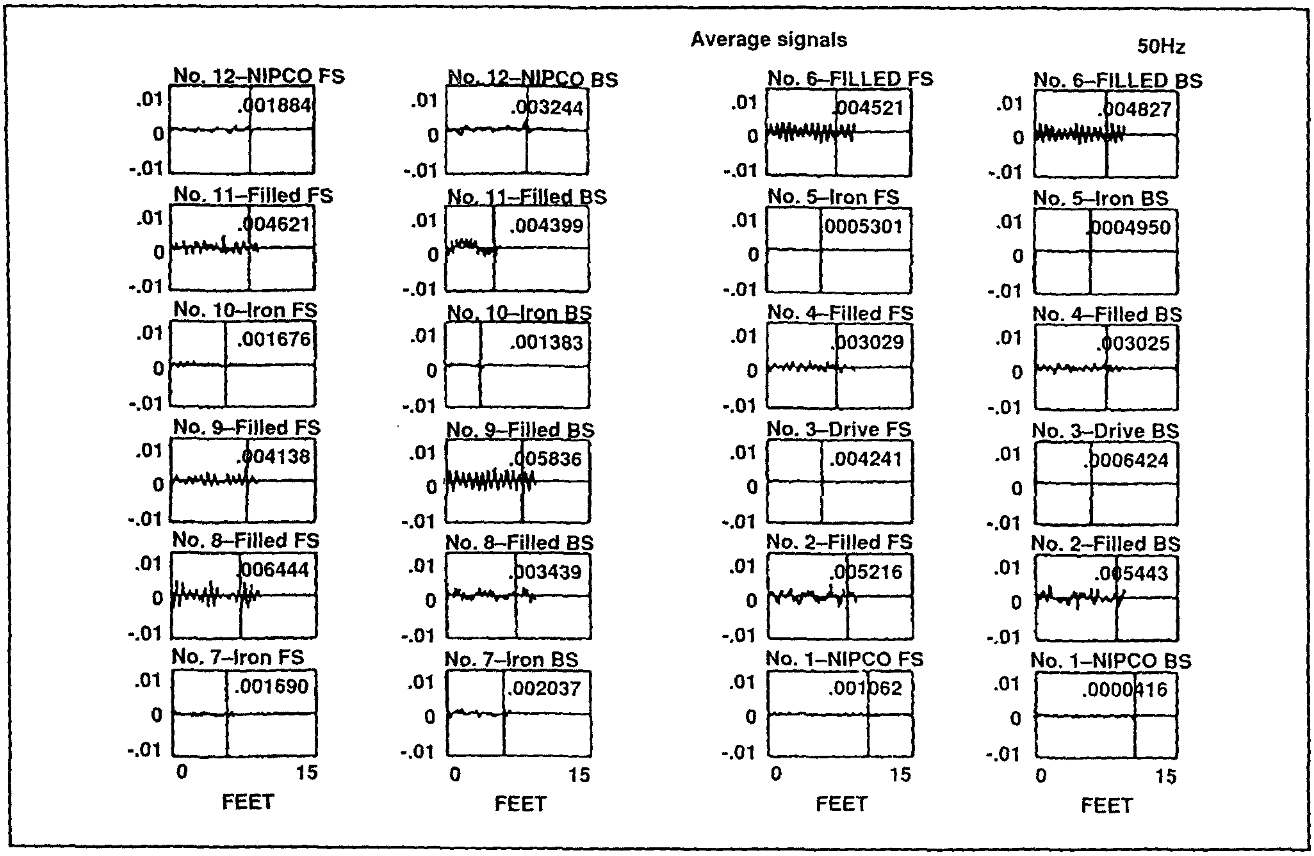
16. Analysis of backing roll on a coater. The graphs on the left depict amplitude over one cycle for load pressure on the coating blade, sheet basis weight, and sheet moisture. The graphs on the right are the associated STA spectra for blade pressure, basis weight, and moisture.



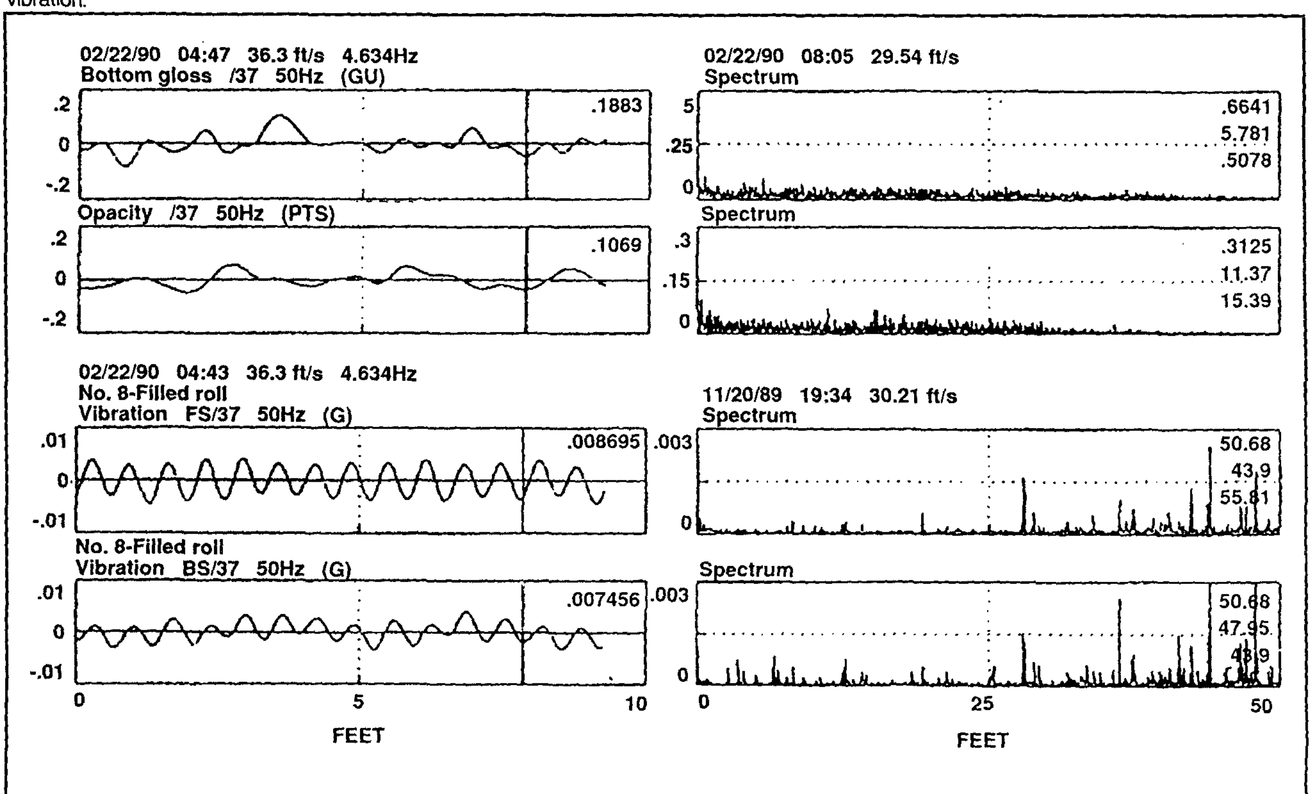
17. Analysis of backing roll vibration at 100 Hz. Left, backing roll No. 2; center, blade loading pressure; right, blade frame



18. Vibration measured on front and back sides of each roll in a 12-roll supercalender



19. Analysis of No. 8 filled roll on 12-roll supercalender. The graphs on the left depict amplitude over one cycle for sheet gloss, sheet opacity, and vibration on the front and back sides of the filled roll. The graphs on the right are the associated STA spectra for gloss, opacity, and roll vibration.



Histories

The information provided by the historical database is helpful in determining which combination of felts, wires, rolls, and covers provides the best performance. Maintenance personnel can use this information to track the deterioration of a specific component. Felts, rolls, paper variables, pump, and screen histories are stored and presented as a 9600-h (400 days) trend. **Figure 14** is a 9600-h history for the bottom felt. The solid horizontal line represents the current value, which can be read off the left axis. The right axis represents current time (0 hours). The calculated felt length and machine speed at the time of measurement are displayed. The time-averaged PTP and average vibration levels are stored for each felt (front and back). The mill can label and date the performance of each felt to enable comparison of different felts. An additional history display for the previous felt is more detailed than the 400-day history and provides a useful picture of the current felt condition throughout its service life.

Figure 15 is a display depicting the performance history of a press roll (fourth-press top roll). The vertical lines indicate the roll-change times. Vibration levels for different rolls are easily identified.

Coaters

Coater performance can be tracked simply by monitoring vibration of the backing roll and coating blade as well as the load pressure of the coating blade. The time-averaged spectra in **Fig. 16** show a correlation between blade load pressure and sheet basis weight and moisture. **Figure 17** shows that vibration for backing roll No. 2 and for the blade frame is not excessive. However, the middle graph shows that there is a problem based on the coating-blade load pressure.

Supercalenders

Supercalender performance can be monitored with an efficiency system. **Figure 18** shows typical results for vibration on the front and back sides of each roll in a 12-roll supercalender. **Figure 19** correlates the vibration analysis for the No. 8 roll with sheet gloss and opacity.

Summary

With papermakers constantly under pressure to increase production and quality, optimization of paper-machine performance is essential. An on-line efficiency system provides the papermaker with a powerful tool for monitoring machine performance, analyzing problems, and improving product quality.□

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