

## **PAPER MACHINE SPEED INCREASE TRIAL**

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### **ABSTRACT**

A large-scale speed trial of a paper machine was successfully completed using temporarily mounted transducers and data acquisition systems. Logistical and environmental issues were overcome to produce an understanding of the machine's vibration behavior at future speeds, and to shed light on ongoing vibration issues.

### **1. INTRODUCTION**

Beta Machinery Analysis participated in a smaller scale speed trial on this paper machine in 2000. At that time, the speed of the paper machine was 1350 mpm, and the recommendations resulting from the trial allowed the machine to be brought up to the current 1450 mpm. Based on the success of the first speed trial, Beta was again retained by the client to evaluate the paper machine performance at higher reel speeds. The current reel speed is between 1450 and 1460 mpm. This trial covered a speed range of 1500 to 1600 mpm, and occurred just prior to the June 2004 shutdown. It is planned to take the speed up to 1600 mpm in the future.

The job was quite challenging from an instrumentation viewpoint, as initially a large number of rolls were identified for potential monitoring during the speed trial. After much discussion, the number of measurement points was reduced to a manageable number, but still afforded reasonable coverage of the paper machine. A total of 88 channels of vibration data and 6 channels of tachometer data were taken on the former, press, dryer and calender sections over the speed range with roughly an even split of channels between drive and tending sides of the machine. There were environmental difficulties that had to be overcome: moisture, temperature and generally being out of the way of the day to day operations and the roll and felt change areas.

As well, during the shutdown mechanical natural frequency testing was done to determine the possibility of resonances contributing to known vibration concerns.

The press section of this machine has a number of similarly sized rolls on a compact frame. As a result there is significant "cross talk" between rolls. This results in a complex vibration pattern. As well there were a number of known vibration issues in the dryer at current machine speeds that may have been aggravated by the speed increase.

## 2. Technological Challenges or “You Want to Use HOW MANY Transducers?”

The job had many challenges on the instrumentation side of it. All of the vibration and tachometer channels monitored during the speed trial were temporarily mounted on the machine. And as can be seen in Figure 1 the paper machine is quite large and preparations were being made for roll and felt changes during the following shutdown. The monitoring equipment and cabling had to be placed in such a way as not to interfere with normal day to day operations, or the shutdown.

The monitoring equipment was placed at two separate locations. The first location was near the wet end of the dryer just beyond the blue roll on the floor in Figure 1. That equipment monitored the former and press sections, as well as a few channels from the back side of the dryer. The instrumentation consisted of: a 56 channel data acquisition and vibration analysis system; and a 16 channel digital tape recorder.

The second monitoring location was located at the calender stack end of the dryer. The equipment used there was a 16 channel data acquisition instrument and another 16 channel digital tape recorder.

The resulting cabling setups at the monitoring end are shown in Figures 2 and 3. Bookkeeping became its own challenge during the setup. It was vitally important to be certain that any given accelerometer was mounted in the correct location, the correct direction, and was then connected to the correct channel on the appropriate instrument.



Figure 1. The paper machine viewed from the former section towards the dryer end, showing the front or tending side of the machine. To the right of the paper machine can be seen the roll and felt laydown areas needed for the shutdown. Monitoring equipment was located just beyond the blue roll at the wet end of the dryer, and at the far end of the dryer.



Figure 2. Former and press data acquisition equipment monitoring 56 vibration and 4 tachometer channels.



Figure 3. Dryer and calender stack monitoring equipment 32 vibration and 2 tachometer channels.

Cabling was a problem in itself. The paper machine is approximately 10 metres in width, 10 meters in height and 100 meters in length. Running individual coaxial cable from each transducer back to the appropriate connector on the monitoring instrumentation could have been done. However, the time to install the monitoring equipment, the aggravation factor, and the probability of bad connections or loss of signals would have been much larger. To save cable length and time, three “umbilical” cables were used to run to the back side of the paper machine. The umbilical consists of a cable bundle in its own insulation sheet that contains multiple individual shielded conductors. The ends of the umbilical cables have serial connectors that attach to a box at each end with BNC connectors for each channel. Three 30 metre umbilical

cables were used: one with 12 channels and two with 16 channels. The 12 channel umbilical is shown in Figures 4 and 5.

Shorter 16 metre coax cables were run from the individual accelerometers to a designated BNC connector on the umbilical. At the data acquisition end, short 1.5 – 2 metre BNC cables were then used to connect from the umbilical to the appropriate channel on the analyzer, power supplies or recorder. Even with the use of the umbilical cables over 1.7 km of coax cable was run.



Figure 4. The 12 channel umbilical cable – 30 metres in length with serial connector ends.

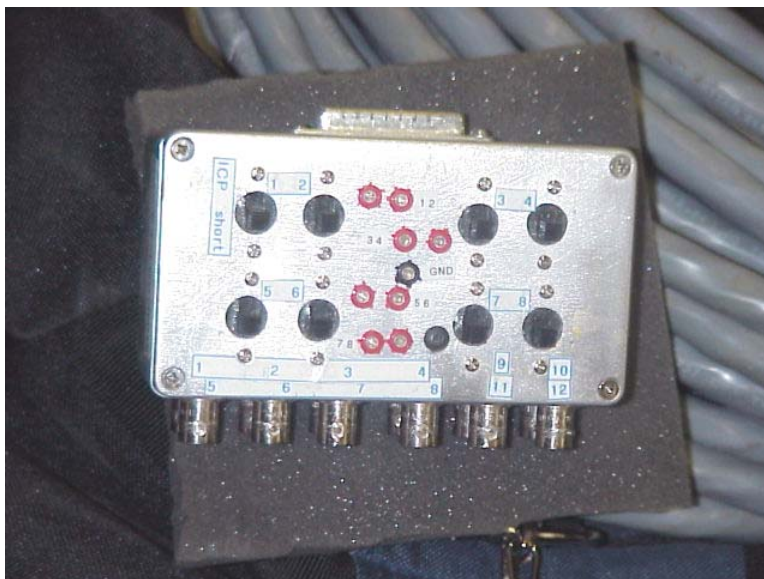


Figure 5. One of the umbilical end boxes with BNC connectors for 12 channels.

Moisture was an additional problem, especially in the former and press sections of the paper machine. Although the number of connectors were minimized, it was necessary to connect two BNC cables with a union. These connections, along with the mil-spec connections at the accelerometer ends were not water resistant. To overcome this, all connections in the wet end of the paper machine were covered with electrical splicing tape as shown in Figure 6. The tape bonds to itself where it overlaps and forms a reasonably water tight seal. This is an extra time consuming step, but the reduced time and aggravation due to wet connections was well worth it. However, the tape is difficult to remove when tearing down the equipment.



Figure 6. A BNC to BNC connection covered with electrical splicing tape to make water resistant.

### 3. The Measurements

The speed trial showed that, in general, the paper machine behaved well over the desired speed range. However, over the machine's history there have been several important vibration issues: high vibration of the 3<sup>rd</sup> press and pick-up felt stretch rolls; barring of the 4<sup>th</sup> press profile roll; and widespread vibration in the dryer at the suction blow roll rotational frequency. The following section will detail the speed trial and mechanical natural frequency testing results concerning these issues.

The 3<sup>rd</sup> press and pick-up felt stretch rolls are similarly mounted on the top of the press section. At the time of the speed trial in 2000, both of these rolls had diameters approximately equal to many of the wet felt rolls in the press. The beating between the rolls resulted in a highly cyclic severe vibration in the horizontal direction, particularly on these two stretch rolls. To reduce the response of the stretch rolls, the diameters of both were increased by approximately 10% in 2001.

During the June 2004 speed trial, the horizontal vibration of both stretch rolls was found to be a combination of the rotational frequencies of the larger stretch rolls (8.1 Hz at 1500 mpm) and that of the small wet felt rolls (9.0 Hz at 1500 mpm). At 1500 mpm the largest component of vibration was at the wet felt rolls rotational. As the speed was increased to the mid-point of the speed range, the vibration at the wet felt roll rotational frequency decreased. As the speed neared 1600 mpm, the vibration at the stretch roll rotational increased. Clearly a resonance was at work.

During the subsequent shutdown, mechanical natural frequency testing on the press section was conducted, with the 3<sup>rd</sup> press stretch roll and its frame receiving considerable effort. The impact testing shows that stretch roll had natural frequencies at 9, 13 and 47 Hz in the horizontal direction. The first natural frequency at 9 Hz has a mode shape shown in Figure 7 below. The front and back sides of the roll were moving in phase in the longitudinal machine direction. The mode shape of the 13 Hz natural frequency was one where the front and back sides of the roll were moving out of phase in the longitudinal machine direction (see Figure 8). Both of these natural frequencies are rigid body modes of the roll. That is, the roll does not bend, but moves as a rigid body relative to the stretch track. The flexibility appeared to be in the track mechanism itself as the track and support frame motion were at significantly lower amplitudes than the roll itself.

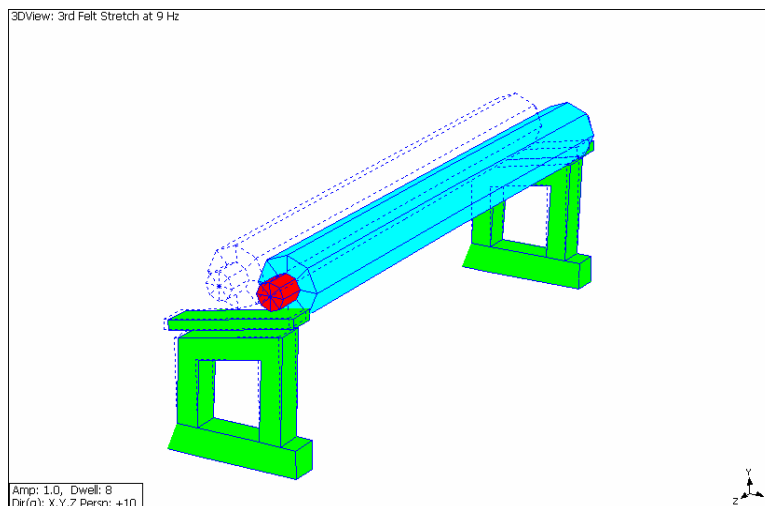


Figure 7. Mode shape of the 9 Hz natural frequency of the 3<sup>rd</sup> press stretch roll.

Recommendations to repair the looseness in the stretch track mechanism and to stiffen the supporting structure have been made. Both of these actions will raise the mechanical natural frequencies of the stretch rolls, reducing the vibration response at higher speeds and increasing the long-term reliability.

Barring of the 4<sup>th</sup> press profile roll had also been a concern. The frequency of the barring had been at 132 Hz. During the speed trial, a vibration component near the barring frequency grew in amplitude, suggesting a possible resonance. A sample spectrum measured on the profile roll bearing housing is shown in Figure 9. This barring frequency vibration disappeared when the sheet was broken and the presses were unloaded.

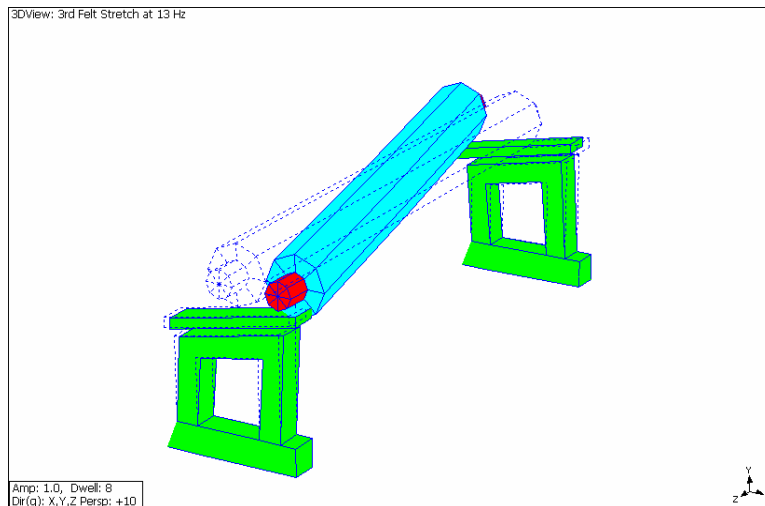


Figure 8. Mode shape of the 13 Hz natural frequency of the 3<sup>rd</sup> press stretch roll.

A portion of the mechanical natural frequency testing of the press section concentrated on finding components with natural frequencies in the barring frequency range during the shutdown. Two were found: the double doctor assembly of the profile roll (see Figure 10 for impact test data); and a cross-machine structural member just below the profile roll (see Figure 11 for impact test data).

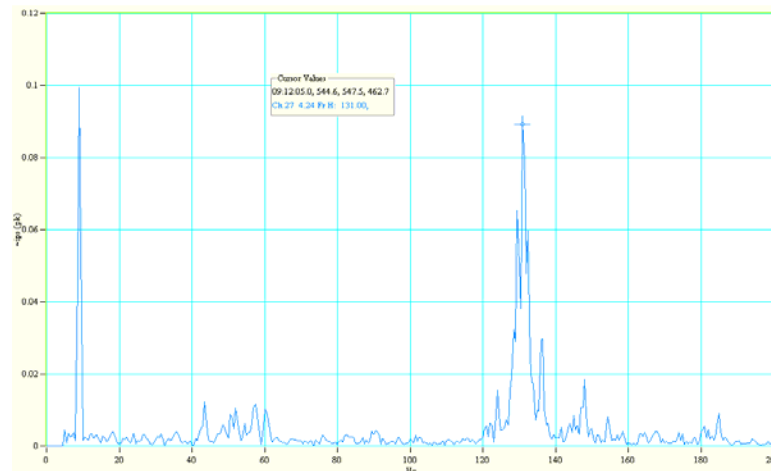


Figure 9. Profile roll vibration spectra showing 1x vibration and 130 – 132 Hz vibration.

The finding of two resonant machine items at 132 Hz makes the onset of barring possible from normally inconsequential events. They include:

- ❑ Felts with an inherent (batt etc) frequency near 132 Hz. Even at very low levels this can excite the presses and start the doctor assembly and cross member resonating.
- ❑ Felt lengths. Felt length to roll diameter ratios can initiate nip vibration at a broad range of frequencies.
- ❑ Roll diameter ratios.
- ❑ Felt or roll cover damage.
- ❑ Doctor chatter. Poor doctor blade performance may result in chattering of the blade creating broad band energy that can excite the assembly's 132 Hz resonance.

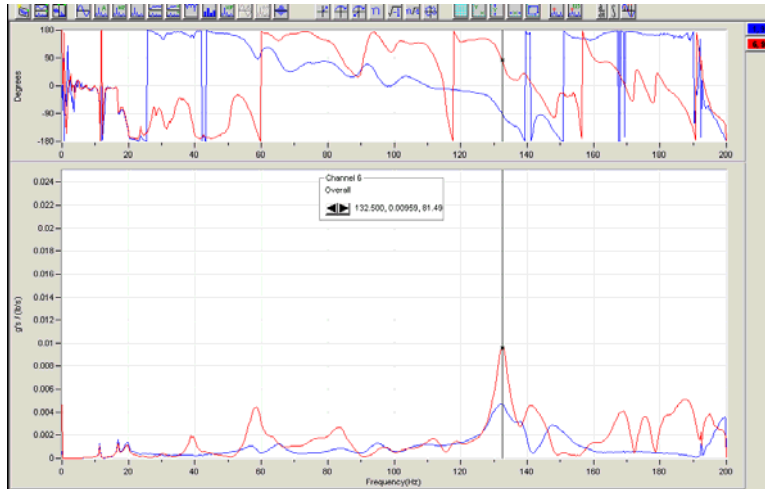


Figure 10. Mechanical natural frequency of profile roll doctor back assembly in the horizontal direction at 132.5 Hz. Chan 1 (blue) is response at the mid-span, and Chan 6 (red) is response at the  $\frac{1}{4}$  point of the doctor back assembly from the front side.

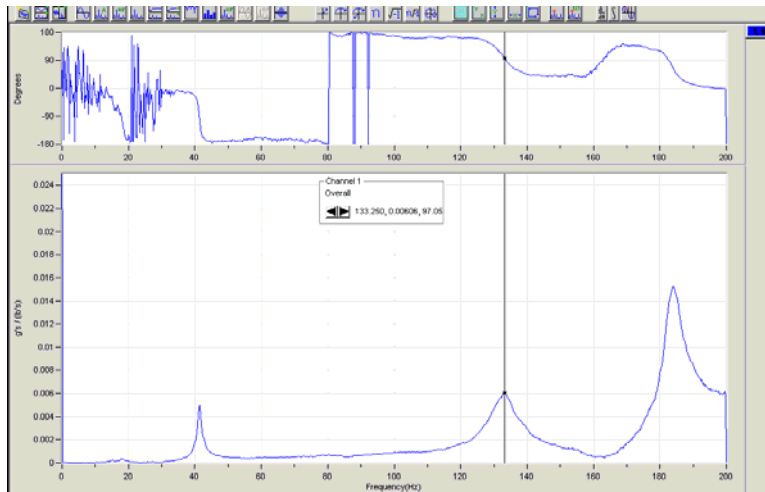


Figure 11. Mechanical natural frequency of cross-machine beam in the 4<sup>th</sup> press in the horizontal direction at 133.25 Hz. The response was measured at the  $\frac{1}{3}$  point from the front side of the beam.

Historically there have also been concerns with widespread vibration at suction blow roll rotational frequencies in the dryer section. Surprisingly this vibration has often been dominant even on the much larger and much heavier dryer cans. A sample spectrum of horizontal vibration of one of the dryers taken during the speed trial is shown in Figure 12.

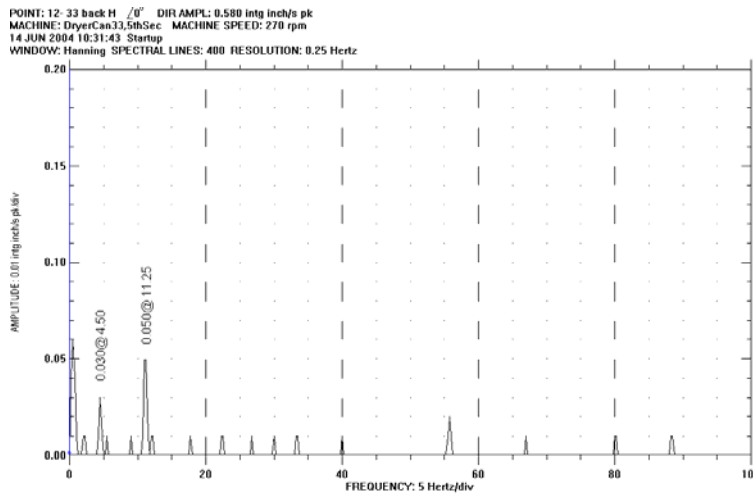


Figure 12. Spectrum of the horizontal vibration of dryer can 33. Note that vibration at suction blow roll rotational (11.25 Hz) was higher than that at dryer can rotational (4.50 Hz).

This widespread response suggested a resonance in the dryer frame. The manufacturer had originally predicted horizontal frame modes of 7.1 Hz and 13.5 Hz. The mechanical natural frequency tests found modes at 7.75 and 11.2 Hz. The mode shapes are shown in Figures 13 and 14 below. Note that only the rolls that had measured responses during the impact tests are shown in the mode shapes. The measured horizontal mode shapes of the dryer frame are similar to those calculated by the vendor. The first mode had a much stronger response to input than the second mode. However, there is obviously sufficient excitation energy imparted by the suction blow rolls at their rotational frequency to cause widespread vibration of the dryer frame.

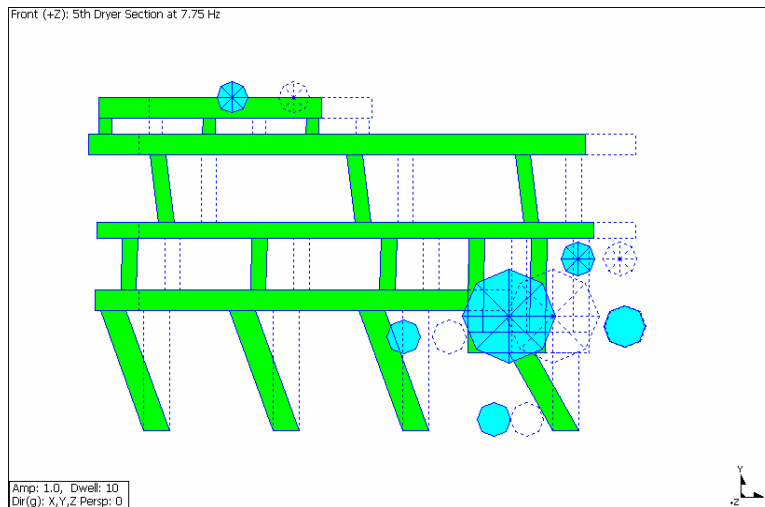


Figure 13. Mode shape of the dryer frame at 7.75 Hz.

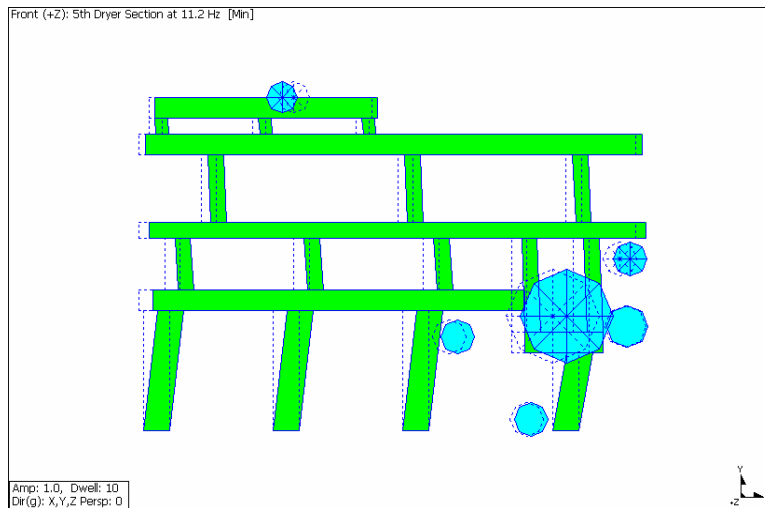


Figure 14. Mode shape of the dryer frame at 11.2 Hz.

#### 4. CONCLUSIONS

It is possible to conduct a large-scale temporary monitoring of a large machine, and produce meaningful results even in environments where moisture, heat and day to day operations and maintenance impinge on the instrumentation.

The speed trial itself showed that the paper machine behaved well in general throughout the speed range. The speed trial measurement, supplemented with natural frequency testing, has created an understanding of ongoing problems and possible future issues. Action plans for the resolution of those issues are currently under discussion with the client.

## **5. BIOGRAPHY**

### **Bill Eckert**

Bill is a graduate of the University of Alberta with a Doctor of Philosophy in Mechanical Engineering in 1992. His doctoral dissertation was entitled *The Application of Finite Element Models to the Analysis and System Identification of Flexible Rotors*. Bill was a postdoctoral fellow and sessional lecturer with the Faculty of Engineering until June of 1997. At that time he accepted a position as a Project and Research Engineer with Beta Machinery Analysis.

During his tenure at Beta, Bill has worked in both finite element modelling and field troubleshooting. His finite element experience includes dynamic and static modelling of: compressor package structural steel (skids), process piping and vessels. His field experience includes: balancing of generators and electric motors, and troubleshooting of vibration and pulsation problems around reciprocating, centrifugal and screw compressors, centrifugal and plunger pumps, turbo-expanders, pulp and paper machines, and gearboxes.

### **Steve Lawn**

Steve has a wide range of rotating machinery experience in the petrochemical and pulp and paper industries in his 30 year career. He has been responsible for plant start-ups, trouble-shooting machinery problems, and developing predictive maintenance programs. In recent months, he has been heavily involved in pump and generator issues at a large wastewater treatment facility.