IN-SITU™ ROLL BALANCING: A REVOLUTIONARY METHOD FOR IMPROVING DRYER SECTION PERFORMANCE

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ABSTRACT: As machine operating speed increases, unbalance forces increase dramatically, leading to equipment reliability and product quality problems. Correcting dryer unbalance presents significant technical challenges, due to slow rotational speeds and phase influence of nearby dryers. A revolutionary new technique has been developed, using regular maintenance shutdowns as the opportunity for incremental corrections. This approach has proven especially valuable during speed-up projects. This paper describes the challenges, solutions, and benefits of the In-Situ™ Roll Balancing technique.

KEYWORDS: balancing, vibration, dryer

INTRODUCTION

In October 1995, Irving Paper Inc challenged Bretech Engineering Ltd to resolve an existing dryer unbalance problem. At that time, the mill had commenced with a speed-up project, and dryer cylinder unbalance had been detected during a dynamic analysis conducted by Bretech. Mill engineers agreed that corrective action was required, especially since the unbalance forces will increase proportionally to the square of the speed increase (see Eq 1). However, production requirements did not permit an extended shutdown (ie opportunity for corrective action) within the paper machine rebuild project schedule.

The conventional method of balancing dryers is the vector or influence coefficient method. The effect of a trial mass added at a correction plane is measured, and mathematically related to the position and size of the trial mass. With this information, the trial mass can be sized and relocated to eliminate unbalance forces. This technique requires that each dryer is mechanically isolated (ie gear pinions and/or dryer felts removed) and rotated using an external drive mechanism – therefore extended shutdowns are required to carry out balancing of more than 1 dryer.

In order to conform to the speed-up project schedule (and achieve production goals), Bretech engineers commenced with development of a new dryer balancing procedure. The most significant predetermined constraint was that corrective action must be conducted during a scheduled maintenance shutdown.

BALANCING BASICS

ISO 1925 – Mechanical vibration – Balancing - Vocabulary defines unbalance as: "That condition which exists in a rotor when vibratory force or motion is imparted to its bearings as a result of centrifugal forces". Centrifugal forces are generated when the mass center of gravity or principle inertia axis does not correspond with the center of rotation. The amounts and position of rotor mass unbalance are in general unknown and cannot be measured directly. The corrections for mass unbalance must be determined through measurement of the rotor's vibration response to a known trial weight (influence coefficient method). Balancing is both an art and science. The science is involved in the use of single and 2-plane vector graphical or calculator procedures. The art is involved in the selection of balance planes and speeds, as well as trial mass sizes and locations. It must be recognized that field balancing is performed to minimize vibration at a selected location on a machine. Therefore, a global weight is attached to the rotor to compensate for local mass unbalance at several locations. This may introduce localized stresses in the rotor.[1]

The forces generated by mass unbalance depend on the mass of the rotor or unbalance weight, its mounted eccentricity, and the rotor speed, as shown in Eq 1 below, where,

$$F = \left[\frac{W}{g} e\omega^2 \right]$$

Eq 1 • Force due to Unbalance

F = Force due to mass unbalance, lb.
W = Rotor Weight, lb
g = gravitational constant = 386.1 in/sec^2
e = eccentricity, in
ω = rotor speed, rad/sec

Since the force is proportional to the rotor speed squared, residual unbalance may become a serious problem following paper machine speed-ups.

There are 2 types of unbalance, static and dynamic, as illustrated in Figs 1 & 2, below.

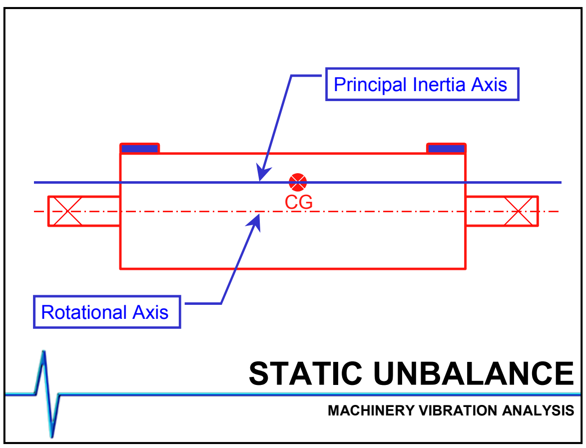

Fig 1 • Static Unbalance

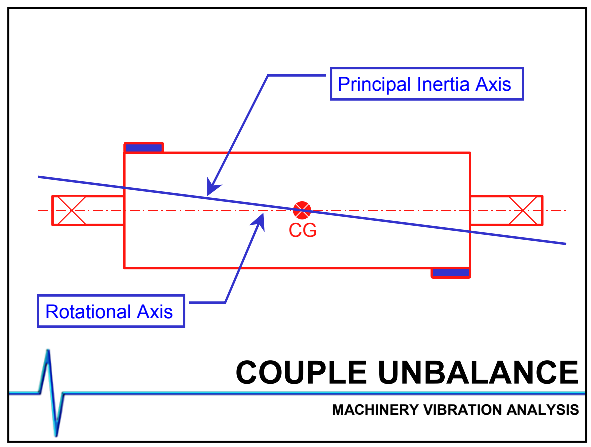

Fig 2 • Couple Unbalance

Pure static and pure couple unbalance rarely occur in real rotors; rather some combination of each type, known as Dynamic Unbalance typically occurs. The amount of couple unbalance, indicated by phase relationship of the end planes, provides an indication of whether the unbalance may be resolved using a single plane or 2-plane solution.

For conventional balancing, proper trial mass selection saves valuable time (and may prevent destruction of machinery). Jackson[2] has suggested that a trial mass should be used which yields a force of not more than 10% of the static weight of the rotor. For the proposed new balancing technique, it was proposed that the ideal trial mass vector (magnitude and phase) equals the unbalance force vector. This would permit installation of unbalance correction weights during scheduled maintenance shutdowns.

Although the subject of dryer cylinder unbalance is not explicitly dealt with in ISO1940, a target vibration response of 0.04 in/sec PK was established, mostly from practical experience. This is approximately equivalent to the permissible residual unbalance, u_{per}, allowed by ISO1940 G1.

Dryer cylinder balancing inherently presents specific technical challenges;

- ✓ **slow rotating speeds (< 300 rpm)**
- ✓ **phase influence of nearby dryers (see Fig 3)**

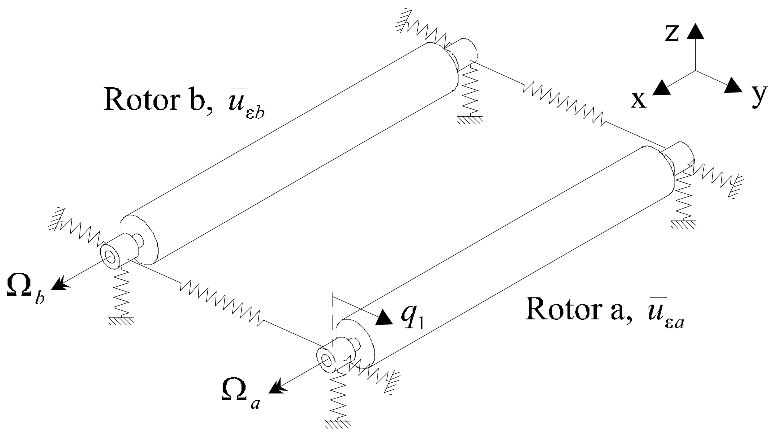

Fig 3 • Phase Influence of Nearby Dryers

The proposed new method imposed an additional challenge;

- ✓ **corrective action must be completed within scheduled maintenance shutdowns, of 12 hours or less**

PROCEDURE DEVELOPMENT AND TESTING

Extensive laboratory and field testing was conducted to evaluate the technical challenges, and proposed solutions.

The laboratory test model is shown in Fig 4, below.

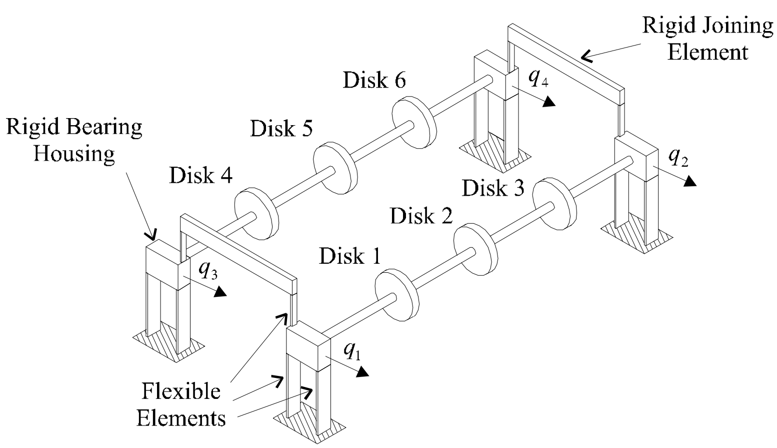

Fig 4 • Laboratory Test Model

Several methods, including resonance balancing and field intensity measurements, were evaluated in detail, with limited practical success.

Following extensive testing, a practical application of the influence coefficient method was developed. This technique uses high resolution, high accuracy measurements of the rotating speed vector (magnitude and phase) to calculate the initial trial mass, ensuring a size and location resulting in significant improvement. Corrective action may be easily accomplished within an 8 hour shutdown. Subsequent shutdowns are an opportunity to further improve the mechanical condition through trim balancing.

Accurate field measurements of low frequency vibrations (< 10 rpm) are difficult due to signal-to-noise ratio and linear frequency response of sensors. For balancing applications, this is a particularly important issue, since phase is measured relative to the 1X turning speed signal component. Recent developments in sensor technology and low noise signal conditioning were applied with success.

The phase influence of nearby rolls was evaluated in great detail. This proved to be an especially difficult field test, when it was discovered that the peak magnitude and phase (at 1X turning speed) of many dryers is unstable (probably due to phase influence). One particular analysis was performed on two nearby rolls turning at slightly different speeds (felt driven dryers with different diameters). The speed difference, measured using a laser tachometer, was found to be approximately 1 revolution in 10 minutes. A corresponding change in amplitude and phase (approximately 60° on one roll) was observed. This circumstance is not typical, since many dryer cylinders are connected through gears, and therefore synchronous.

INSTRUMENTS AND EQUIPMENT

As previously mentioned, special purpose low frequency accelerometers were utilized. Accurate measurement of phase was accomplished using a reflective reference marker and self powered laser sensor (0 – 5 vdc TTL output). Prior to use, a calibration check was conducted on all sensors and cables, using a calibrated handheld shaker.

Measurements were acquired using industry standard multi-channel spectrum analyzers.

Correction weights were designed to mount external to the dryer cylinder, for easy and quick installation. This design uses dryer head bolts to attach external weights.

PROCEDURE DETAILS

✓ **Baseline Assessment**

A baseline analysis of the dryers, felt rolls, and support structure is required. Subsequent measurements and analysis is performed on a regular basis (prior to and/or immediately following each maintenance shutdown). Each dryer is measured using very low frequency accelerometers, capable of withstanding high temperatures, in the radial machine direction. Phase and amplitude for both sides of the machine is recorded. Triggering is achieved through a reflective marker on each roll. The results are recorded on forms which show entire dryer sections. Phase angles and amplitudes are plotted. The figure provides relative amplitudes and phase angles for an entire section. At a glance, it is generally obvious which rolls are most in need of balancing.

✓ **Identify "the target roll", 1 roll per section**

The "bad actor" is the roll in each section which stands out as having the highest amplitude of motion, and the most stable phase angle from measurement to measurement. The roll may, for example, be moving at 0.3 in/sec, and maintain a phase angle within 30° variation from measurement to measurement, while all rolls in its vicinity are below 0.05 in/sec and phase angles vary significantly. In such an instance it can be concluded that the high amplitude roll is the bad actor, and influenced primarily by itself.

✓ **Detailed analysis of the target rolls**

Once the bad actors have been identified, a detailed analysis of the roll is performed in order to determine if it is influencing adjacent rolls, or vice versa. The roll is analyzed for an extended period (30 minutes) to determine if the phase values vary over time. The best average phase value is used if the total variation is small (within approximately 40°).

✓ **Weight addition to the target rolls**

Weight is added at locations determined during the detailed analysis. The phase angle is used as the absolute location for the weight, no lag is considered. The amount of weight added is dependent upon the amplitude observed when performing the detailed analysis. A preliminary estimation for amount of mass required per amplitude measured has been worked out for all cans in the dryer. The estimation will be improved as more rolls are balanced.

✓ **Trim balancing**

The predicted weight and location discussed above would ideally provide the perfect balance quality in one run. To date however, this method has not provided a perfect balance quality in one run on more than two of six rolls attempted. For this reason, ICM calculations are performed following weight additions, and adjustments are made during subsequent shut downs.

✓ **Analysis of the entire dryer**

Following the weight additions, a complete dryer analysis is performed, identical to the baseline assessment. Results of weight additions are observed and preparations are made for the next shut down period.

Fig 5 • Field Measurements at drive side

Fig 6 • Field Measurements at tending side

RESULTS

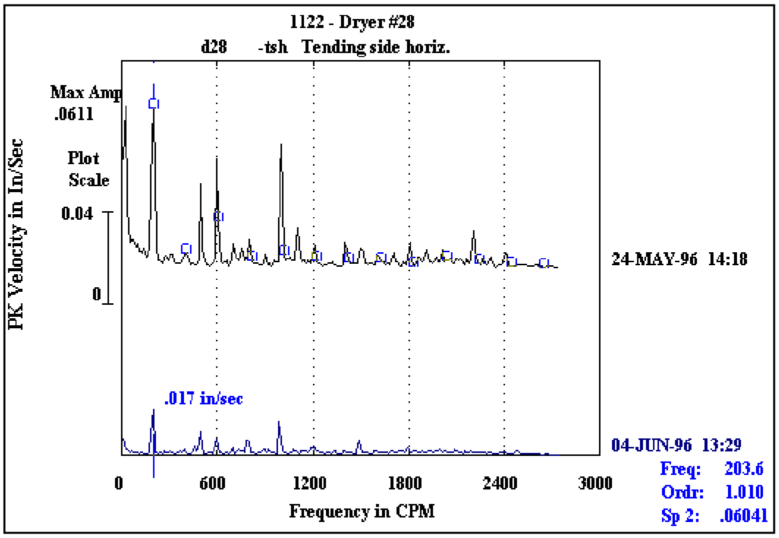

Fig 7 • 1st Field Balance Attempt (Before and After Single Run Balance)

✓ Dryer # 28

Fig 7, above shows excellent results achieved on single run balancing. Initially, can #28 in the dryer section was measured to have over 0.06 in/sec vibration. Following the addition of weight to the tending side plane, amplitudes were reduced to below 0.02 in/sec. Reductions on other rolls have been achieved, but not so dramatic as on this one.

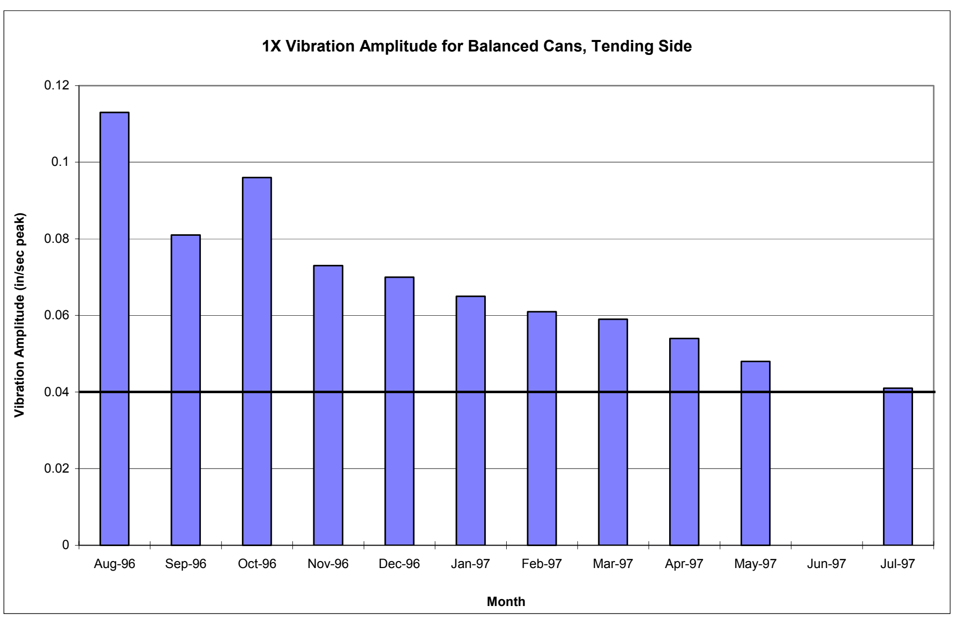

Fig 8 • Overall Project Results at Irving Paper Inc PM#2
(Note: Speed Increase 2800 to 3200 fpm)

RESULTS (continued)

✓ **Dryer #3**

Can #3 was the primary reason for beginning this project initially. When first tested, its amplitudes were observed to be as high as 0.4 in/sec peak. This is equivalent to approximately 40 mils peak to peak displacement. The movement was visually obvious, resulting in considerable anxiety among operators and maintenance staff. The process of balancing the roll in place required 7 shut downs. The preliminary balancing methods were developed to the procedure presented in this paper. Following the addition of over 80 lbs to the roll radius, amplitudes have been reduced to a high of .14 in/sec. It has been determined that no further balancing can be performed on this roll until the adjacent roll is balanced. Through beat frequency analysis, it has been estimated that the adjacent can is contributing approximately 70% of the vibration to can #3. The can movement is no longer excessively visible.

As indicated on Fig 10, below, forces due to felt roll unbalance were detected at dryer cylinder bearings. Balancing felt rolls in place is particularly challenging due to flexible nature of rolls (ie may operate above 1st natural frequency) and excessive runout. Procedure development is in progress.

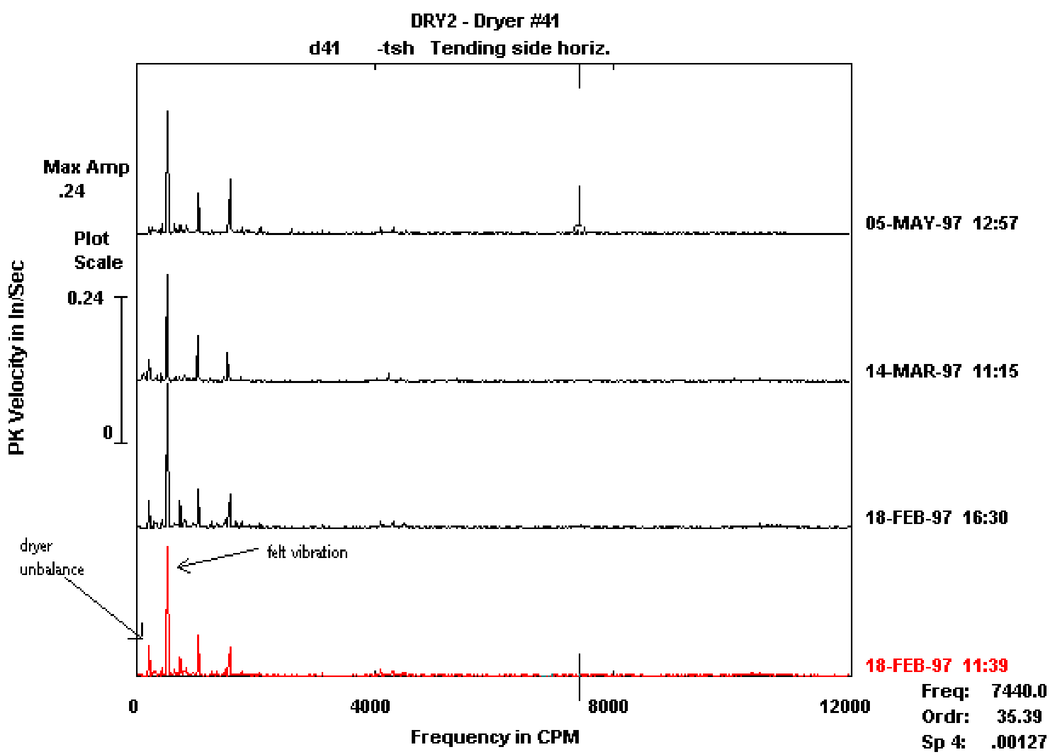

Fig 9 • Vibration Force due to Felt Roll Unbalance

Based on generally good results at PM#2, the same procedure was applied at PM#1 with equally good results.

Subsequent to development of the procedure, successful application of this method has been conducted at various facilities throughout Canada and United States. However, several outstanding technical issues remain unresolved, including problems related to flooded dryers and felt slippage.

CONCLUSIONS

A reliable method of balancing dryer cylinders has been developed and successfully implemented. This technique applies the basic concepts of vector balancing, with modifications that ensure the installed trial mass resolves unbalance. This method permits a corrective action during scheduled maintenance shutdowns.

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ABOUT THE AUTHOR

Mike Robichaud is an expert in machine condition monitoring and vibration control. He is a licensed professional engineer with over 20 years practical experience, mainly in heavy industry. Since establishing Bretech Engineering Ltd in 1989, Mike has resolved numerous vibration problems for clients worldwide in the pulp & paper, oil & gas, mining, and power generation industries. Mike has also managed the development and implementation of condition monitoring programs at various industrial and commercial facilities.

Mr Robichaud has achieved **Certified Vibration Specialist III**. He served as 1998/99 President of the Canadian Machinery Vibration Association (CMVA) and on the board of directors of the Vibration Institute. He is also a member of the Canadian Advisory Committee to ISO TC108/SC5 (Mechanical Vibration and Shock / Condition Monitoring and Diagnostics of Machines). Mike has authored and presented numerous technical papers and short courses on the subjects of vibration analysis and condition monitoring. Working closely with the Bretech Team, Mike has developed various specialized techniques, including **IN-SITU™ Roll Balancing** and **SCORE™ Maintenance Assessment**.