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# EQUIPMENT FAILURES

*Mills need to use predictive and preventive maintenance programs*

**T**oday's pulp and paper mills are very high-tech, sophisticated manufacturing operations. Because mill operating conditions can be extremely harsh, equipment can deteriorate rapidly and, in some cases, even fail. Because the consequences of equipment failure are so severe in terms of time, money, and, in some rare cases, lives, mills need to make preventive maintenance a primary concern.

A description of a comprehensive predictive maintenance program for all pulp and paper mill equipment is too extensive for a single article. Thus, this article will present only a brief overview of recent predictive maintenance techniques as applied to the most vital pieces of equipment in the industry, including Yankee dryers, paper machines, digesters, and recovery boilers.

## YANKEE DRYERS

In the last decade, the industry has found a large number of Yankee dryers with cracking in the head. In several instances, the cracking resulted in catastrophic failures. Due to this failure potential and the relatively long lead times and expenses associated with procuring a replacement, mills should inspect Yankee dryers on a regular/annual basis. More frequent inspections may be desirable when excessive rates of erosion, corrosion, or other conditions of deterioration appear.

From 1985 to 1990, there were eight known cases of cracks appearing in the heads of Yankee dryers. In all of these cases, a corrosion product buildup at the head-to-shell interface preceded the cracking (see Fig. 1).

The buildup of this corrosion product gradually reduces the contact between the head and the shell flange sections.

The loss of uniform contact between the head and the shell flanges, in turn, increases the bolt clamping forces. This creates bending of the head section and high tensile stresses in the bolt hole circle and/or spigot fit area. Over time, these stresses may produce mechanical fatigue cracking in the head or shell.

The time frame in which the mechanical fatigue cracking will develop varies from dryer to dryer. It depends on many factors, including the extent of the corrosion product buildup, the materials involved, the operating pressures, the speed at which the dryer rotates, the cross-sectional thickness, the forces introduced by the bolting, etc.

Mills should already know that there are industry guidelines covering the inspection of Yankee dryers to determine their suitability for continued service. Moreover, mills can use several



**Fig. 1 (above):** Corrosion product build up at the head to shell surface.

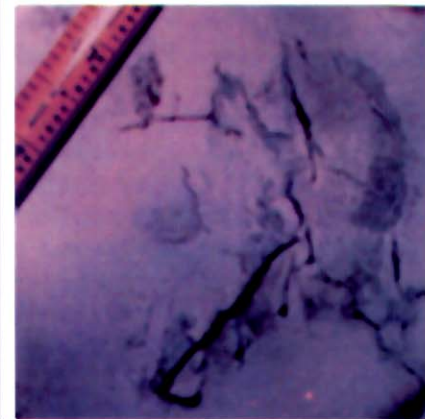
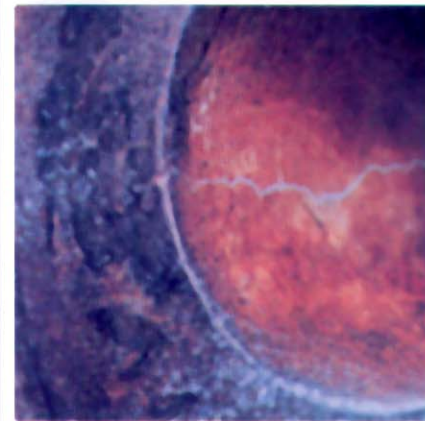
**Fig. 2 (above right):** Cracking in bolt hole circle detected by borescopic examination.

**Fig. 3 (right):** Casting shrinkage in dryer roll head.

inspection techniques to detect incipient or progressive cracking. The first of these inspections involves checking of the interference fit (spigot fit) between the head and shell with feeler gages. If the interference fit between the head and shell measures .002-in. to .005-in., the spigot fit is intact and progressive cracking is likely to occur. If the interference fit measures .008-in. or greater, mills should make additional inspections.

The first of these additional inspections involves a corrosion check. Essentially, this inspection involves cleaning the head-to-shell interface on the front and drive sides of the dryer and performing a detailed visual inspection of the head-to-shell interface. A dryer in good condition will exhibit a "line" or metal-to-metal interface at the head-to-shell joint. If corrosion is present, it will appear as a dark band rather than a line. Industry-wide standards consider the presence of corrosion to be a serious problem—a potential precursor to progressive cracking.

In addition to performing an examination for corrosion buildup, mills should measure "shell runout," or the "wobble" about the longitudinal axis. These mea-



surements will allow the mill to detect incipient or progressive head-to-shell cracking.

Another method of detecting incipient or progressive cracking in the head is a head tilt check, which measures head tilt by using dial indicators located on the head flange. Mill personnel turn the dryer by hand and record readings at every bolt. A tilt of .05-inch or more is significant.

If mills use these inspection techniques on a regular basis, they will detect incipient or progressive cracking. The mills can verify the cracking by borescopic examination (see Figure 2). In addition, they can use ultrasonic examination to size and detect cracking.

The ultrasonic examination of Yankee dryers is not simple because these vessels contain gray cast iron materials. In ultrasonic examinations, gray primarily shows variations in the microstructure and casting defects, such as voids, shrinkage cavities and nonmetallic inclusions. In recent years, vendors have developed and refined specialized techniques for providing clear images with gray materials. These techniques use specially cut angle beam probes in conjunction with digital signal processing equipment to accurately locate and size subsurface cracks and defects. To insure the accuracy of the testing results, the techniques employ a series of reference standards machined from actual flawed sections for calibration.

Once the mill locates and determines the size of a crack, it may perform a finite element analysis of the dryer to determine the stress at the crack root. Using the dryer's operating history and the stress data, the mill can determine a crack propagation rate. Based on this information, the mill can also determine an inspection schedule and a "time for maintenance."

### PAPER MACHINES

In 1989, four cast iron dryer rolls in a paper machine at a southern U.S. mill failed catastrophically, resulting in a fatality. Although these rolls were not of recent vintage, their failure raised concern regarding the integrity of dryer rolls in other paper machines.

Prior to this failure, mill inspection of paper machines was cursory—at best. Subsequently, however, mills are making magnetic particle examination of at least 50% of the shell and both the tend-

*Fig. 4 (below): Typical appearance of periodic weld overlays made in a continuous digester.*

*Fig. 5 (right and below right): Examples of thinning in generating tubes.*



ing and drive side heads. The inspections also involve ultrasonic wall thickness determinations of the shell and hardness determinations.

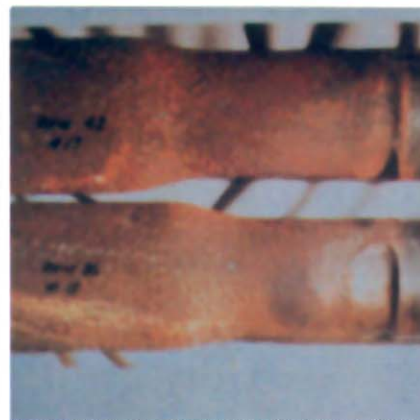
Because the purpose of these inspections is to detect dryer rolls in danger of catastrophic failure, mills should perform them on a regular basis. Extreme care should be taken, however, in interpreting the results of these inspections as dryer rolls represent cast iron products that may contain a large number of rather alarming looking indications, which are, in fact, inconsequential. For instance, the indication shown in Fig. 3 represents a casting shrinkage defect that has not progressed since installation.

To insure the continued integrity of paper machines, operators should perform rigorous periodic inspections of the components in that machine. To insure that these inspections do not result in unwarranted replacements, mill personnel should carefully document and interpret results of the inspections.

Another predictive maintenance technique that should be applied to paper machines on a more regular basis is vibration monitoring. Each piece of rotating equipment produces a characteristic and predictable vibration signal. Equipment can measure these signatures, and mills can periodically compare the current signature to earlier ones taken when the machine was in good operating condition.

### DIGESTERS

In a TAPPI survey concerning corrosion in the lower cooking zone of digesters,



several mills reported that their digesters had indeed shown corrosion in the lower cooking zone. One mill indicated that its digester had experienced a 0.25 inch reduction in wall thickness in less than one year. It appears that a combination of conditions produced by normal operations triggered the corrosive behavior.

At some mills, employees apply weld overlays in stages by building up the wall thickness in the most severely corroded area by approximately 1/4 inch to 3/8 inch during each outage stage (see Fig. 4). During such weld buildup stages, very careful monitoring of the quality of the wall thickness (i.e., complete weld fusion) is essential. Mill employees can then apply additional weld overlay thickness levels during convenient plant outages at 6-to-12 month intervals until the original design wall thickness is restored.

Other mills perform their weld overlays in a "one shot" deal. This may be a time-consuming process depending on the reductions in wall thickness. Moreover, the "one-shot" approach may be less cost effective than multiple weld overlay stages.

There are currently three options

available for weld overlaying: carbon steel, stainless steel, and Inconel weld filler metal materials. While there are advantages to each material, most experts consider carbon steel to be the preferred material because it prevents the preferential corrosion that occurs in the heat affected zone of a dissimilar metal weld in black liquor service.

Once the digester is back to its original thickness (or before it has deteriorated to an extent where repair welding is required), the mill should consider the use of cathodic or anodic protection.

**RECOVERY BOILERS**

A recovery boiler probably represents the largest single capital expenditure a pulp mill will ever make. Unfortunately, it probably also represents the single most dangerous component in a pulp mill. A simple tube leak in a recovery boiler can result in a smelt bath reaction and subsequent catastrophic explosion. The area of greatest concern for a mill, therefore, should be leaks through waterwall tubes because of the close proximity of the waterwall tube sections to the smelt bath.

Waterwall tube sections are not the only places where leaks occur. They also appear in screen tubes and roof tubes with the ensuing result of smelt bath explosions. The major cause of these leaks is defective tube-to-tube welds, including shop welds made by induction welding or other welding processes, and field welds. As a result, mills should subject welds in the waterwall section to 100% radiographic examination, even though this is not required by Section I of the ASME Boiler and Pressure Vessel Code.

Mills can perform a radiographic examination of tube-to-tube welds by using an elliptical exposure rather than two exposures 0° and 90° apart. The use of the elliptical exposure significantly reduces the cost and time required to complete the radiographic examination of the boiler. It must be recognized-at this time-that elliptical exposures may not detect every defect which exists in a tube-to-tube weld. If, for instance, a weld contains sidewall lack of fusion, an elliptical radiographic examination may not detect it.

Despite the increased cost associated with using two radiographic exposures per weld rather than one, an owner or operator planning a new boiler or substantial retubing in an existing boiler should give consideration to using two radiographic exposures per weld. The

cost of replacing a recovery boiler far outweighs the cost of nondestructive examinations.

Stress enhanced corrosion is another primary area of concern in the waterwall section of recovery boilers. The fatigue associated with constant expansion and contraction of tubes is the cause of stress

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enhanced corrosion. Heating of the fire-side of the tubes on the inside of the furnace results in expansion of the steel. Because the back or "cold side" of the tube is at a lower temperature, it will experience a commensurately reduced degree of expansion. As a result, the cold side experiences tensile stresses. If the cold side tubes also experience an additional restraint, such as a restraint imposed by welded attachments, they will experience additional tensile stresses. If these combined tensile stresses are of sufficient magnitude, they may cause cracking. This type of cracking may also occur on the fire side of waterwall tubes near the membrane welds.

The initial and primary cause of cracking is fatigue and stresses at a restraint location. The stress-enhanced corrosion cracking tends to occur in recovery boilers that are nearly 20 years old or older. Cracking is extremely difficult to detect because it develops along the inside diameter of the tubes at the location of a tie bar or a scallop bar. Moreover, the attachment weld tends to make volumetric inspection difficult. The only reasonable method of detecting stress corrosion cracking is periodic tube sampling in conjunction with radiographic examination.

Another area of concern in recovery boilers is tube thinning. This thinning or metal wastage along the surface of the tube is typical of erosion which abrades the surface of the tube uniformly and smoothly (see Fig. 5). It is significantly different from corrosion that tends to result in nonuniform deterioration with preferential attack along the grain boundaries. The mechanism of erosion is also supported by the localized condition representing one side of the tube circumference.

There is some disagreement as to the cause of tube thinning. This erosion is

likely to represent a combination of gas flow through the recovery boiler in conjunction with eddy currents caused by soot blowing. The erosion occurs primarily in the tube immediately above the drum surface as a result of the gas flow over the drum surface.

There is a possibility that some high temperature erosion/corrosion may be involved in tube failures. For example, if the fly ash or particulate salt cake entrained in the flu gas is moving at sufficient velocity, it can act as an abrasive and remove the protective oxide coating from the side of the tubes facing the gas flow. This then exposes a bare metal surface. The freshly exposed surface, subject to high temperatures, re-oxidizes, converting a small quantity of the tube material to oxide. If the operating conditions are not altered, this process of alternating scale removal and scale formation will continue unabated until the tube wall in that area is sufficiently thin that it is unable to contain the operating pressure and cracks.

Where generating tubes at locations above the mud drum have failed, the failures usually involve leak-type conditions rather than ruptures. Because of the locations where these leaks may occur as a result of excessive tube erosion, the gas flow through the boiler normally will allow the water passing through the tube at the leak location to flash to steam and be carried through the boiler away from the primary furnace chamber. Because of this, leaks in generating tubes generally have not resulted in smelt bath explosions.

Despite this, it is still considered prudent to perform periodic ultrasonic thickness inspections of generating bank tubing using a digital signal processing or other qualified technique.

**WRAP-UP**

Billions of dollars are wasted or lost by the pulp and paper industry because of the lack of understanding and/or the lack of experience with the performance of engineering materials with respect to the existence or observation of defects, discontinuities, and other indications.

A comprehensive predictive maintenance program will prevent the types of failures described here, or at least provide some forewarning that such a failure is about to occur. Pm

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