Why do TMP refiner plates fail? Given the rigors of thermo-mechanical pulping, plate failure is often the result of a combination of factors working together to influence the ultimate performance and life of the plates.

Thus, the essential first step in improving the performance of refiner plates – and, indeed, of the entire pulping operation of a mill – is to correctly diagnose the causes leading to plate failure.

It is also important to remember that predominant plate failure modes in one mill may not necessarily be the same in another.

Plate failure is influenced by the unique conditions of a particular mill, including: specific energy, load stability, consistency, pH, wood species, and chip cleanliness.

However, as these systems have become more sophisticated, the potential for improved plate performance has increased. Operator training, advanced feeding systems, advanced refiner designs, improved steam evacuation and wood chip systems, and computerized control systems have all contributed.

There are six distinct types of plate failure, each falling under one of two basic categories:

A. Process Variables:

These are variables unique to an individual mill or a specific pulping situation, such as improper feeding systems, steam evacuation problems, the presence of foreign materials, improper chip washing, etc.

The typical plate failure modes associated with process variables are serration, bar wear, and bar breakage.

B. Normal Operating Conditions:

These are conditions to be expected during the normal operations of any TMP mill, such as high temperatures, pressures, and peripheral speeds.

The typical plate failure modes associated with normal operating conditions are cavitation, corrosion, and bar edge rounding.

Though plate failure is usually a combination of several of these failure modes, it is still important to identify the primary cause of plate failure, given a specific set of operating variables.
To achieve this objective, a study was conducted in-house and at several independent laboratories. The refiner plates first were physically examined. Then, metallurgical samples from the plates were examined under optical and electron microscopes. Finally, samples were tested for hardness and chemical analysis.

These were some of the observations:

1. Serration:

Serration is typified by circumferential grooving (Fig. 1). It has been suggested that this is caused by electro-mechanical machining, but that does not appear to be the case for TMP applications.¹

As Figure 2 shows, plate-to-plate contact has caused actual surface melting to occur. Cast microstructures and microporosity are present in the resolidified layers.

The surface is deformed in the direction of rotation. Grains are smeared in layers across the surface of the bar (Fig. 3). Surface cracking is also apparent, possibly due to the high temperature transfer and resolidification of the bar surface. A build-up of material can be seen at both the leading and trailing edge of the bar.

The reason that a given serration pattern occurs is not known. The answer to this may give a clue to its prevention.

2. Bar Wear:

Figure 4 shows the effects of wear caused by the stress of hard particles flowing over the plates. The harder the particles, the greater the stress and impact on the surface, as is usually the case with primary refining. Secondary refining, associated with the erosive forces of a constant solution, would be more likely to create a low-stress situation.

Though many of the plates examined showed a circumferential wear pattern, this did not appear to be the cause of plate failure. However, the micro-cracking evident in Figure 5 could lead to failure when occurring in combination with other factors, such as cavitation or corrosion.

Abrasion-resistant refiner plates would require alloys selected for high-impact strength and wear resistance.

3. Bar Breakage:

Bar breakage is characterized by the fracture of bars at their base in a band across the plate (Fig. 6). Because plate rotation causes a chain reaction, single-bar breakage was not observed.
Usually bar breakage occurs in areas where the bars are unsupported, such as in the transition zone between changes in bar configuration.

Bar breakage is a direct result of mechanical failure caused by forces with an energy level that cannot be absorbed by the refiner plates. Examples are plate clashing and tramp materials in the refiner.

Since this is possible in all refiners, a degree of safety must be built into the plates by controlling the plate design and the materials selected.

Bar-Stronight Ratio is a key factor in plate design. As shown in Figure 7, a certain ratio of bar height to bar width must be maintained to resist bar breakage.

The strategic location of dams and interconnecting transition zones can also influence breakage-resistance.

Refiner plate alloys offer different impact strengths, depending on their chemical analysis, heat treatment, and resulting microstructure. There is a distinct difference in the breakage-resistance of specific alloys. Research to determine the exact values of impact strength required for optimum TMP refining is on-going.

4. Cavitation:

Refiner plates are subjected to the repeated forming and collapsing of vapor bubbles along the wetted surface.

This phenomenon is associated with areas of pressure drop, usually where there is an interruption in fluid flow. An associated phenomenon is liquid droplet impingement which causes erosion due to the repeated impact of liquid droplets on a surface.

Both phenomena would lead to the creation of deep pits, or cavitation, beneath the surface of the material.

The breaker bar section of a plate is subject to flow conditions ideal for cavitation (Fig. 8). However, this defect is not particularly detrimental to plate performance.

Cavitation along the bar edges at the periphery of the plate is more detrimental. Quite possibly this defect, as shown in Figure 9, is caused by a cavitation in combination with localized corrosion and erosion.

Figure 10 shows how the matrix of the material is preferentially attacked, leaving unsupported carbides on the surface. These carbides are brittle and easily broken off by mechanical wear. This leaves deep pits which give a cavitated appearance. The presence of microshrinkage tends to accentuate the corrosion/erosion pattern.

Material selection would appear to be the most controllable variable.

5. Corrosion:

Though isolated corrosion is not readily apparent because of the great amount of mechanical wear involved with refining, corrosive defects are definitely present in used TMP refiner plates.

Earlier we discussed the relationship of preferential corrosion and bar-edge cavitation. Figure 11 shows areas of preferential chemical attack as seen under an electron microscope. Attack is along grain boundaries, outlining the solidification structure.
Figure 12 shows the deep pits left when carbides are removed, creating planes of weakness in the structure. Combined with the erosive forces of TMP refining, this defect can cause pieces of material to be fractured from the wear surface.

The cause of preferential corrosion is not conclusive. One possibility is chromium depletion of the matrix adjacent to the carbide structure. Another is galvanic corrosion, where a potential exists between the eutectic carbides and the matrix. Possibly this type of attack could be driven by the potential created from the stray currents of power generating motors.

Whatever the cause, corrosive environments do exist in refiners, a condition that probably can be alleviated by the selection of corrosion-resistant materials.

6. Bar Edge Rounding:

Bar-edge rounding is exemplified by rounding or blunting of the leading bar edge (Fig. 13). While the exact requirements of a proper bar edge are not known, it is clear that bar edges must remain sharp and a certain degree of bar roughness must be maintained for optimal TMP refining.

Normal wear conditions in a TMP refiner can lead to a greater or lesser degree of bar-edge rounding, depending on the plate materials selected.

Despite proper chemistries and hardnnesses, poor thermal treatments can lead to the formation of ferrite in the microstructure of either white irons or stainless steels.

Fig. 12: Deep pits where carbides are removed.

In the case of white irons, this is related to slow cooling rates that allow the formation of pearlite at grain boundaries. For stainless steels, high-temperature tempering will allow the transformation of retained austenite to ferrite.

Because ferrite is the softest phase possible, its presence can cause more rapid edge deterioration.

The exact relationship of microstructure to proper bar edge is currently under investigation.

Conclusion:

Selecting the proper design and alloy materials for TMP refiner plates requires a thorough understanding of the mill conditions leading to plate failure.

The purpose of this article has been to explain and illustrate some of the more typical plate failure modes and their probable causes. In a later article we will focus on how to use this knowledge to optimize refiner plate performance by matching plate metallurgy and design to specific TMP applications.

References
