IMPROVING MILL PRODUCTIVITY WITH ADVANCED WEAR PROTECTION SOLUTIONS

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ABSTRACT

Extended intervals between scheduled outages, shorter shutdown durations and dwindling maintenance budgets have increased the pulp and paper industry's reliance on advanced wear protection technologies to lengthen conveyance equipment life and maintain production quality. The use of advanced wear protection on equipment, as a preventative maintenance measure, can enable mills to reliably extend planned outage cycles, while reducing overall costs and diminishing the risk of unscheduled outages.

This presentation will summarize recent field erosion experiments conducted by NorskeCanada's Port Alberni Division on their power boiler's induced draft (ID) fan, in an attempt to reduce severe wear, increase fan productivity, and prolong intervals between planned outage cycles. By replacing chrome carbide weld overlays with brazed tungsten carbide protection, the mill successfully extended the fan's effective run time from eight months to twelve months, and ultimately, plans to lengthen their scheduled power boiler outage cycle from once a year, to once every two years. They expect to realize an immediate annual savings of $150,000 in fuel costs, and an additional $150,000 biannually in maintenance costs.

An independent review of severe wear protection methods on power boiler ID fans in the power generation industry will also be presented, with similar results. Outcomes from pulp and paper mill applications of brazed tungsten carbide cladding on other conveyance equipment will also be briefly discussed.

INTRODUCTION

In today's pulp and paper industry, extending scheduled maintenance shutdowns is becoming increasingly important. At the same time, mill managers, process engineers and maintenance staff have become accountable for increasing mill efficiency and reducing downtime and operational costs, while adhering to strict environmental standards.

The erosion and corrosion of steel components continues to plague mill personnel by triggering expensive equipment replacements, costly and inconvenient downtime, and damaging reductions in mill productivity. The use of advanced wear protection on equipment, such as induced draft fans, chutes, screws, elbows, pumps and other material conveyance components, can enable mills to reliably extend scheduled outage cycles while reducing maintenance budgets and diminishing the risk of unexpected downtime.

Practical field experiences and independent tests have demonstrated that brazed tungsten carbide cladding, as an alternative to chrome carbide weld overlay and other wear resistant coatings, provides increased erosion, corrosion and abrasion protection. Brazed tungsten carbide cladding has been proven to be superior in fly ash conveyance fans, and in other industrial applications, where both erosion and corrosion are significant mechanisms of failure. The reliable severe wear protection offered by brazed tungsten carbide cladding can reduce mill operating costs, improve productivity and lessen the opportunity for unplanned outages.

NORSKECANADA, PORT ALBERNI DIVISION

NorskeCanada, a Canadian-owned corporation, is one of North America's largest groundwood pulp and paper manufacturers. They operate four community-based mills and a paper recycling division with a total annual capacity of 2.5 million metric tons of pulp, paper and containerboard. Port Alberni and its sister mills in Crofton, Elk Falls and Powell River are located within a 160-kilometer radius in the coastal region of southwestern British

Columbia.

Positioned on the west coast of Vancouver Island, NorskeCanada's Port Alberni Division is one of the largest producers of telephone directory and lightweight coated papers in North America. With an annual production capacity of 432,000 metric tons, the Port Alberni Division manufactures papers used to print telephone books, magazines, catalogs, and flyers.

The mill produces 480 metric tons of pulp each day using the Chemi Thermo Mechanical Pulp (CTMP) method. CTMP is produced when wood chips are heated and then ground between jagged metal plates to divide the fibers from the wood. Chemicals, including sodium sulfite and sodium hydrosulfite, are applied to soften and condition the chips in order to make a stronger pulp. The CTMP process requires a sizeable energy supply, a portion of which Port Alberni produces internally.

POWER BOILER DESCRIPTION

The mill's steam plant converts fuel energy into steam through the use of a 1978 Combustion Engineering, Inc. power boiler with a 1997 converted Kvaerner fluidized sand bed. The boiler is fueled by hog fuel produced by local logging operations and sawmills. It has a boiler steam capacity (MCR) of 400,000 pounds per hour and burns an average of 900 metric tons of hog fuel each day.

Figure 1. Port Alberni's Power Boiler ID Fan

By-products generated from the power boiler include highly erosive ash and flue gases, which are transported by air to the precipitator, where the fly ash and other particulate matter are removed. The boiler utilizes an induced draft (ID) fan (see Figure 1) to pull flue gases from the boiler and force them through to the precipitator. The mill uses one operating ID fan and one spare fan rotor for the power boiler. The ID fans were manufactured by Baron Industries, and are composed of 10 forward facing curved fan blades. They have a 300cm (10′) diameter fan wheel with inlets on both sides, and are propelled by a 1,750 horsepower drive fixed to a Liquid Flo fluid coupling, used to control the 800 RPM fan speed.

Maintenance is performed on boiler equipment during the required annual boiler outage. The ID fan wheel is replaced with a spare wheel every year, and extensive repairs are performed on the fan housing, inlet dampers, and multiclone sections upstream from the fan. The boiler shutdown duration is dictated by the amount of time required to overhaul the fan. In order to lengthen fan life from one to two years, reduce operational and maintenance costs, and minimize shutdown periods associated with the fan overhaul, the mill addressed the severe wear complications affecting their boiler and conveyance equipment.

SEVERE WEAR CONCERNS FACING THE BOILER ID FAN

Port Alberni began to experience severe wear on their power boiler's ID fan in 1997, when the boiler was converted from a stoker grate to a fluidized-bed system. Wear problems were detected when the plant was forced to increase fan speeds to achieve optimum fan capacity. An inspection revealed that the outer portions of the fan's blades were experiencing extreme wear, caused by the highly erosive components in the fly ash passing through the fan at elevated speeds. Eventually, sections of the fan blades wore completely through, reducing fan capacity.

Prior to 2001, Port Alberni experimented with chrome carbide weld overlays to protect their ID fans from erosive and abrasive wear. During typical fan operation, fine particles eroded through the hairline cracks inherent to hardface weld overlay materials. These cracks provided a less resistive path for erosive materials to wear through the overlay. Portions of the chrome carbide were undercut and began to detach from the fan, as shown in Figure 2. Premature fan deterioration proved costly and inconvenient for mill operators.

The mill operates the ID fan at 75% to 80% of its full capacity. Plant operators began detecting a decrease in fan capacity approximately eight months after installing the ID fan protected with chrome carbide weld overlays. Fan speed was steadily increased to maintain desired capacity. After ten months of operation, the wear and productivity losses exceeded the ability to compensate with increased speed. The fan was unable to achieve required boiler loading for the remaining two months, until the planned outage period. As a result, the steam plant was forced to burn more costly natural gas in their second boiler to achieve the required mill steam load. Over a two month period, these added fuel costs were estimated at $150,000.


Figure 2. Fan Blades Protected by Chrome Carbide Weld Overlays after Twelve Months in Operation

Severe erosive wear of ID fan components can also create unbalanced vibrations, causing the fan to trip. Fan failure would result in incremental boiler fuel costs of approximately $80,000 per 24 hour period (based on June 2004 gas prices) and could potentially effect daily paper production, resulting in lost revenue.

Reduced power boiler ID fan efficiency placed both financial and productivity strains on mill performance. The chrome carbide weld overlays affixed to the fan were not providing acceptable erosion protection. As a result, NorskeCanada Port Alberni eagerly sought improved preventative wear solutions to mitigate these adverse effects.

POTENTIAL WEAR SOLUTIONS

In an attempt to decrease costs associated with reduced fan efficiency and downtime, and to extend the useful life of the ID fan to two years, maintenance engineers at Port Alberni began investigating alternative wear protection solutions. In June 2001, the plant initiated the testing of various protective materials by placing sample coupons on the ID fan. They requested 102mm (4″) x 254mm (10″) samples, bent with a radius of 2032mm (80″), of brazed tungsten carbide cladding, chrome carbide weld overlay and hard alloy steel. The samples were attached to the scroll of the fan housing, and were monitored for erosion performance for a period of six months.

Chrome Carbide Weld Overlay

A chrome carbide weld overlay plate is composed of a mild steel base with a chromium carbide weld layer. The combination creates a wear resistant plate with a moderately formable backing that can be welded directly onto existing components. Chrome carbide weld overlay can be applied and repaired in the field and is fairly inexpensive to purchase and apply. The thickness of the overlay can be increased by applying multiple weld layers. However, multiple weld layers create a fragile surface, leading to check cracking. Thicker applications are not practical on ID fans due to weight concerns, and the instability and extra motor pull that is created.

Welding variations can severely alter the wear resistant characteristics of overlays. Overlays can be applied unevenly, creating cracks between the welds. The welding process produces intense heating and cooling, often resulting in overlay distortion and severe cracking. In high impact environments, these flaws can create plate spalling and breaking.

Check cracking is inherent to chrome carbide weld overlays, and material pre-heating, post-heating, slow cooling, and stress relieving may be needed. Extreme localized heating, combined with the difficulty in controlling cooling rates, typically results in material check cracking. Channeling will occur as surface check cracks create a path for erosive materials to undermine the base material, jeopardizing structural integrity and possibly leading to a catastrophic failure.

Wear Resistant Alloy Steel

A variety of hard alloy steels can be used as wear protection. The alloy steel tested by Port Alberni was a heat treatable, low alloy steel with a low sulfur content. This material is inexpensive, readily available and, similarly to weld overlays, is formable and can be welded directly onto existing components in the field. However, protection offered by low alloy steels in extreme wear environments is inherently limited. Field applied steel plates are also susceptible to check cracking, which can propagate into the base material and the attachment weld, causing a possible catastrophic fan failure.

Infiltration Brazed Tungsten Carbide Cladding

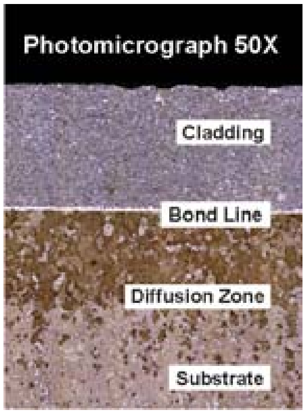

Figure 3. Photomicrograph of Infiltration Brazed Tungsten Carbide Cladding

The infiltration brazing method constitutes filling, by capillary action, a porous coating or structure with molten filler metal. While there are many methods for applying the carbide and braze in preparation for infiltration braze coating, the principle technique used to manufacture the brazed tungsten carbide cladding discussed in this paper involves a non-woven preformed cloth. The particles used in this process are sized and mixed to provide a homogeneous, stable, dense coating.

The superior wear protection provided by brazed tungsten carbide cladding can be attributed to the benefits of the brazing process, which metallurgically bonds the hard particles and matrix metal to the substrate. The cladding is virtually crack-free due to the controlled application and cooling during the brazing process. Hard particle densities of more than 70%, by volume, can also be achieved during the brazing process (see photomicrograph in Figure 3). The method does not generate significant carbon dilution into the protective layer, ensuring a uniform wear rate.

The brazed tungsten carbide cladding can not be field applied or repaired due to the nature of the brazing method. The process also places size limitations on the pieces that can be directly clad. To enable field installation on large equipment, such as ID fans, liners with brazed tungsten carbide cladding applied to a thin substrate are fabricated and then weld-attached on site. Brazed tungsten carbide cladding has a higher initial installation cost than traditional protection methods. However, financial profitability analysis often demonstrates that this advanced wear protection can generate overall cash savings and higher Internal Rate of Returns (IRR) by extending capital equipment life.

TEST RESULTS

The tested wear protective materials were compared in December 2001, after six months of ID fan operation. Figure 4 displays the results. The test clearly established that the infiltration brazed tungsten carbide cladding outperformed both the heat treatable, low alloy steel and the chrome carbide weld overlay in the highly erosive power boiler environment. Only the brazed tungsten carbide cladding retained its original length, as shown in Figure 5. Due to the success of the sample brazed tungsten carbide cladding, the Port Alberni mill proceeded to cover portions of the ID fan blades with clad liners during their next annual shutdown.

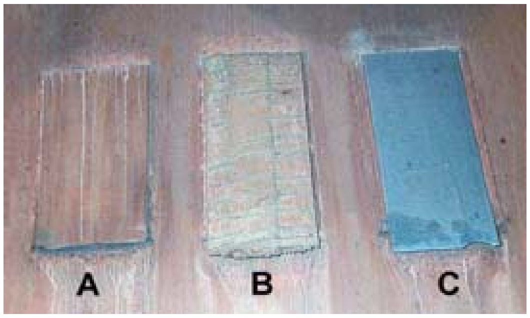

Figure 4. Comparison of Wear Results after Six Months. A. Alloy Steel, B. Chrome Carbide Weld Overlay, C. Brazed Tungsten Carbide Cladding

Figure 5. Comparison of Material Lengths after Six Months. A. Alloy Steel, B. Chrome Carbide Weld Overlay, C. Brazed Tungsten Carbide Cladding

BRAZED TUNGSTEN CARBIDE CLADDING APPLICATION

In July 2002, Port Alberni installed ten 838mm (33″) x 445mm (17 1/2″) fan blade liners protected with 1.5mm (0.060″) of infiltration brazed tungsten carbide cladding on the operating ID fan (Fan A). Fan A, with components protected by brazed tungsten carbide cladding, maintained optimal capacity through 12 months of continuous operation. In July 2003, a routine inspection of Fan A revealed a wear zone in the middle of the liner's leading edge (see Figure 6).

Also in July 2003, the mill expanded the brazed tungsten carbide application to their auxiliary fan (Fan B), cladding blades and areas on the center of the support web, which had historically experienced extensive wear. The Fan B application involved cladding ten 838mm (33″) x 445mm (17 1/2″) fan blade liners, ten 1067mm (42″) x 241mm (9 1/2″) fan blade liners, ten 503mm (19 13/16″) x 584mm (23″) fan rib plates and twenty 287mm (11 5/16″) x 451mm (17 3/4″) fan side plates. The cladding thickness of all fan components remained 1.5mm (0.060″). Fan B also maintained full capacity through 12 months of operation (see Figure 7).

Figure 6. Wear on Fan A after Twelve Months in Operation

Figure 7. Wear on Fan B after Twelve Months in Operation

The mill expanded their use of the cladding again in June 2004, by cladding Fan A with ten 1067mm (42″) x 241mm (9 1/2″) fan blade liners, ten 503mm (19 13/16″) x 584mm (23″) fan rib plates and twenty 287mm (11 5/16″) x 451mm (17 3/4″) fan side plates. In an attempt to extend the useful life of the fan even further, next-generation liners for the 838mm (33″) x 445mm (17 1/2″) blades were developed and installed on Fan A. The entire liner was clad with a 1mm (0.040″) thick application of brazed tungsten carbide, with the high wear portion of the fan receiving an additional 1mm (0.040″) thick application. Due to the predictable wear rate associated with the dense, uniformly applied brazed tungsten carbide cladding, it is expected that the double-clad fan liner will perform at ideal efficiency for at least two years.

As a result, it is anticipated that the mill will begin replacing the power boiler ID fan once every other year instead of annually, resulting in a $150,000 biannual savings in maintenance costs. Additional productivity and opportunity savings were not calculated, but are expected to be significantly greater than the cash outlay savings for the maintenance parts.

The NorskeCanada Port Alberni ID fan experiment demonstrates the real-world wear protection success of brazed tungsten carbide cladding in severe erosive environments. Port Alberni improved their power generation productivity and has plans to enhance other paper production processes through the use of this cladding. Similar results have been realized by independent wear protection testing, performed on comparable ID fans in the power generation industry.

INDEPENDENT COMPARISON DATA

The Electric Power Research Institute (EPRI), a non-profit organization that provides science and technology based solutions to global energy customers, conducted a test to study the effects of erosion on components protected by the most popular wear resistant solutions used in the power generation industry (1). EPRI, in conjunction with the Tennessee Valley Authority (TVA), sought to determine which materials could endure the severe erosion experienced by TVA's Kingston Power Plant's ID fans. The project was initiated in the fall of 2001, and testing was conducted on sixteen wear protected fan blades from six commercial suppliers. Materials tested included infiltration brazed tungsten carbide cladding, tungsten carbide High Velocity Oxy-Fuel (HVOF), tungsten carbide plasma spray and chrome carbide weld overlay.

Fan blades were tested over a sixty day trial period on a double inlet, single exhaust, 400,000 CFM Westinghouse model 16MVID with forward curve fan blades (see Figure 8). Each fan was comprised of 120 blades with a shaft speed of 593 RPM. Wear protected blades were distributed throughout the fan. In order to facilitate balancing, each pair of test blades was installed 180 degrees apart. Because material wear rates were unknown, test organizers were careful to distribute the test blades so that erosion induced weight change would not require fan rebalancing.

Figure 8. TVA's ID Fan

At the conclusion of the sixty day test, all of the blades, except the four blades clad with infiltration brazed tungsten carbide, were removed. The blades protected with tungsten carbide weld overlay and tungsten carbide HVOF were removed due to complete coating wear-through. The blades protected with chrome carbide weld overlay experienced a material loss of 3mm (0.120″), suffered from a crack at the center junction plate and experienced extreme wear at the leading edge.

Measurements taken from the infiltration brazed tungsten carbide blades showed a material loss of only .25mm (0.010″) at the leading edge. Based on the test results, the Kingston plant began the process of retrofitting ID fans with blades clad with infiltration brazed tungsten carbide. The first blades were installed in October 2002. After seven months of runtime, the tungsten carbide clad blades showed a material loss of .4mm (0.014″) or less, primarily at the leading edge. Based on the applied tungsten carbide cladding thickness, the blades are expected to last more than 24 months, four times the life of unprotected fan blades.

The test results and field performance data show that the densely packed tungsten carbide cladding wears at a uniform and predictable rate. Bond strengths are estimated to be in excess of 482,300 kPa, resulting in a protective barrier that is highly resistant to chipping, cracking and flaking. These results are consistent with those derived from the NorskeCanada Port Alberni ID fan experiment.

CONCLUSION

Advanced wear protection applied to equipment components can reduce operating and maintenance costs, reliably extend planned outages, and reduce the risk of unscheduled downtime. The NorskeCanada Port Alberni Division field experience, along with other independent testing, has determined that infiltration brazed tungsten carbide cladding outperforms other protection methods in highly erosive power boiler environments. The Port Alberni Division is confident that the cladding will perform similarly well in other mill applications, including hog, chip and ash handling equipment.

Other pulp and paper mills have found comparable success protecting their equipment with brazed tungsten carbide cladding. A mill more than doubled the useful life of their Worthington 90cm (3′) x 60cm (2′) white liquor slurry pump (shown in Figure 9) from six months to more than 13 months, by replacing their stainless steel protection with brazed tungsten carbide cladding. Another plant improved their productivity by cladding their 900cm (30′) lime kiln feed screw. The previous screw, protected by chrome carbide weld overlay, had an expected life of one year with weld repairs every six months. The screw clad with brazed tungsten carbide has lasted over two and a half years and is still in operation.

Figure 9. Slurry Pump Protected by Brazed Tungsten Carbide Cladding

Reference(s)

1 EPRI. *TVA Kingston Fossil Plant - Induced Draft Fan Erosion.* Palo Alto, California: Electric Power Research Institute Report, ER&TA Number 021807, May 2002.