COLLABORATION TO REDUCE WEAR AND CORROSION COST FOR THE MINING INDUSTRY

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Abstract

It is a common objective for all the mining industries to reduce the cost of maintenance and reliability due to wear and corrosion issues. Larger gains and faster progress could be achieved by a more concerted collaboration. With this vision, the National Research Council (NRC)/Industry Mining Materials Wear and Corrosion Consortium was founded in 1996. The consortium has expanded to 14 members, including mining companies, equipment manufacturers and materials suppliers. During the last 19 years, through the collaborative wear materials research program within the consortium, the expertise, the unique capabilities, and the materials database, NRC have helped the consortium members to reduce the severe wear and corrosion damage that translates to high costs and production losses incurred during mining and mineral processing. Some very significant improvements in the battle to control wear/corrosion and improve performance are presented.

Introduction

Wear and corrosion issues can be found for almost all the equipment employed in mineral processing within the mining industry. While the grinding process is responsible for the major cost of the wear and corrosion in the hard rock mining sector, components in the slurry transportation process have been the key challenge for the oil sands industry [1]. A typical nickel mine in 2014 could spend more than C$20 million on the grinding media. The grinding of lower grade ores and the harder iron ores could cost much more. The same expense is likely for a hydro-transport line of 70 km for the oil sands operator in 2014. Some of the key components, such as slurry pumps and pipeline u-bends for oil sands, only have a lifetime of less than three months. In 2013, wear was estimated to cost over C$15 billion for maintenance, repair and operations (MRO) for the Canadian mining/mineral processing industry. A major portion of the cost has been attributed to equipment wear and corrosion loss, including materials, labor, and productivity loss. The cost has been increasing significantly with the scale up of production and a decrease of ore grade quality. The MRO budget at a major oil sands producer has increased from C$450 million in 2003 to C$1.5 billion in 2012.

Wear is usually considered as a materials issue, but is actually a system characteristic in terms of properties of abrasion, properties of wear materials, and contact conditions between the abrasion media and wear resistant materials. Many factors can contribute to the wear loss of materials as summarized in Table I [2]. Any parameter listed in the table could influence the materials performance dramatically, such as the impact angle [3]. Materials evaluations carried out on a laboratory scale have to combine different characterization mechanisms and apply conditions close to the field applications in order to make meaningful conclusions. There are no perfect materials existing to resist wear and corrosion, but wear-resistant materials and operation conditions could be optimized to reduce the wear and corrosion loss. However, the situation for controlling wear issues is complex in the mining processes; it has been a significant challenge for mining operators to select the right materials for further improvement of the operation performance [4-6].

Table I. Factors that Influence Wear Behavior [2]

Abrasive Properties	**Wear Material Properties**	**Contact Conditions**
Particle size	Hardness	Force/impact level
Particle shape	Yield strength	Velocity
Hardness	Elastic modulus	Impact/impingement angle
Yield strength	Ductility	Sliding/rolling
Fracture properties	Toughness	Temperature
Concentration	Work-hardening characteristics	Wet/dry
	Fracture toughness	pH
	Microstructure	
	Corrosion resistance	

NRC/Industry Mining Materials Wear and Corrosion Consortium

The Energy, Mining and Environment (EME) portfolio at the National Research Council (NRC) Canada delivers advanced technology solutions to improve the productivity and competitiveness of Canada's natural resource and utility sectors. We apply our multidisciplinary capabilities to strategic R&D programs that target stakeholder-endorsed challenges to strengthen Canadian supply chains and help companies develop and maintain competitive positions in target markets at home and abroad. Co-investment from clients and stakeholders ensures our program activities remain aligned to market needs and deliver public and private return on investment, enhancing economic, social and environmental well-being. The industry sectors addressed by EME comprise the value chains of mining, oil and gas extraction and processing, primary and fabricated metal products, and electricity and natural gas utilities.

NRC has built comprehensive testing and characterization facilities for evaluation of wear and corrosion-resistant materials and coatings. These facilities include not only commercially available equipment such as low stress abrasion (dry sand rubber wheel/ASTM G65), air jet erosion (ASTM G76), slurry abrasion (ASTM G75/G105) and gouging abrasion (ASTM G81), but also specialized unique testing equipment designed and built by researchers at NRC, such as a scouring erosion system, slurry jet erosion, slurry erosion-corrosion pot and high load scratch test. These facilities cover broad properties for ceramic, metallic, and polymeric materials. These facilities enable the prediction of materials' relative performance under different wear and corrosion attack mechanisms. They provide tools for comparing materials, developing and assessing new materials for particular applications, obtaining information on specific process influences, and quality assurance and specification purposes. NRC also provides materials modeling and simulation packages for optimization and industrial coatings development by thermal spray and cold spray technologies.

As a common objective for all the mining industries is to reduce the cost of maintenance and reliability due to wear and corrosion issues, larger gains and faster progress could be achieved by a more concerted collaboration. With this vision, the NRC/Industry Mining Materials Wear and Corrosion Consortium was founded in 1996, which includes mining operators, equipment manufacturers, and materials suppliers. All the members can access the mining material data from the evaluations at NRC and share the results obtained by the members. In addition, NRC provides technical solutions to clients through collaboration projects by either co-investment or fee-for-service projects for exclusive delivery.

Along with the critical influences of process conditions and equipment design on the extent of wear attack, the selection and development of optimized/improved wear resistant materials is of extremely high importance to control and mitigate damage and losses. This dictated the agreed consortium collaboration strategy which has been formulated as:

- Identify and focus performance improvement efforts on the most important problem areas;
- Confirm attack mechanisms and correlate worn surfaces from service to those obtained in testing;
- Increase wear evaluation and characterization capabilities to meet critical needs;
- Determine and compare the properties and structures of the entire spectrum of mining wear materials under a variety of relevant abrasion and erosion conditions that simulate industrial service, correlate properties and material systems with conditions, and establish fundamental influences;
- Produce a comprehensive Wear Materials Properties database that is updated regularly and is accessible to qualified industrial sponsors;
- Use the database as an in-house reference and provide controlled external access and consulting resources to assist in materials selection, for Quality Assurance and specifications/standards compilation, in wear parts failure analysis, and to facilitate development of more wear resistant products.

NRC has compiled a database from materials evaluation programs performed since 1996. To date the properties of these materials include air jet erosion, ASTM G65, high stress abrasion, impact abrasion, and slurry jet erosion. The database also includes wear and hardness test results and associated conditions/compositions and SEM images of the materials' microstructures. The materials are from multiple forms and manufacturing processes such as bulk materials and surface modification systems, including weld overlays, claddings, coatings, and diffusion layers. Figure 1 shows an illustration of online access to the NRC wear materials properties database. The database has been widely used for design, materials specification and construction. Along with the consortium operation, the members have found the following benefits:

Figure 1. Illustration of online access for the NRC wear material properties database.

- Access to the world class research facilities, including specialized equipment developed at NRC;
- Utilization of a comprehensive database of wear-related properties for industrial material selection;
- Participation in a valuable biannual forum to connect with companies, along the value chain, at review meetings;
- Gaining of knowledge on wear and corrosion resistant materials that would have been hard to find otherwise;
- Finding solutions for wear issues through shared success stories;
- Understanding of the needs of end users to optimize or develop products;
- Understanding of the progress of materials suppliers and potential applications for operators;
- Networking for new business opportunities.

Success Stories from the Consortium

During the last 19 years, through the collaborative wear-materials research effort in the consortium, the expertise, the unique capabilities, and the materials database at NRC, consortium members have been able to reduce severe wear of equipment and corrosion damage related to high costs and production losses in mining and mineral processing. Wear is not avoidable, but equipment lifespan can be improved with fresh approaches for the wear and corrosion challenges as shown in Figure 2. NRC has saved the mining industry millions of dollars annually in operating costs by providing materials selection solutions, components design and materials processing improvement. Some selected cases in the battle to control wear and corrosion and improve performance are summarized in Table II.

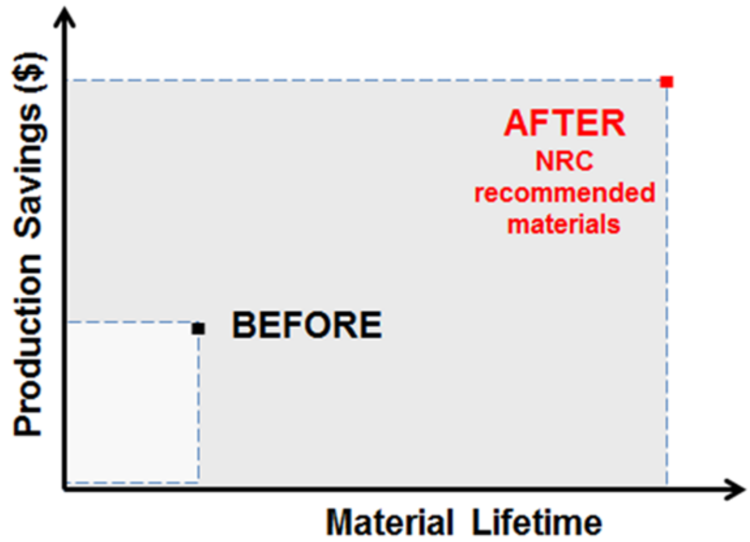

Figure 2. Illustration of NRC impact to the production savings of clients.

Table II. Selected Success Cases to Reduce Wear and Corrosion Loss

Case	Challenge	Solution	Results
Primary Separation Cell	Significant wear loss on a pipe bend in the primary separation cell (PSC) at an oil sands producer	Upgrading PSC line from chromium-carbide overlay (CCO) to a more impact-resistant material identified from the consortium database	Service life increased from 5 weeks to >1 year (Jan. 2015); saved C$112 M/ year from production loss, materials cost, and labor cost
Breaker Plates	Initial medium carbon steel screens required 10 days maintenance per 20 days operation at the field of an oil sands operator; CrC bulk weld and Plasma Transferred Arc Welding (PTAW) WC/Ni-based overlay tried as most successful materials	Laminated CrMo white iron (very high gouging and good sliding abrasion resistance in jaw crusher tests)	Lifespan now >12 months, double the PTAW WC/Ni overlay; increased uptime and production; reduced maintenance charges with comparable plate costs; saving about C$1 million per breaker per year and there are seven breakers in operations
Slurry Mixing Cyclones	Significant wear-loss of slurry mixing cyclones at major oil sands producer	Changed cyclone materials from neoprene-lined carbon steel (CS) to more abrasion-resistant materials found in NRC Database; validated through further testing	Life increased from 300-400 hours to >24,000 hours (March 2015)

Case	Challenge	Solution	Results
Tailings Solvent Recovery Units (TSRU)	Severe wear in downstream TSRU vessels for diluent recovery from heated tailings for hydroheater steam mixing system and feed nozzles in Albian Sands production; service life <1 wk for Stellite overlays on stainless steel hydroheater components, CrC weld overlay, and surface modification coatings on spray nozzles	Sintered tungsten carbide designs for both applications based on NRC Database	Lifetime extended by several months in certain situations
Rotary Coupling for HD Blast Hole Drill	Cracked shock absorber coupling at a hard rock mine; in-house and supplier repairs and modifications unsuccessful	Found failure related to high load/torque system; Designed larger wall section with higher strength weldable steel; Modified welding procedure with finite element analysis; Revised construction material	Superior performance compared to both standard rig and to new advanced OEM option
Shovel Track Link Pads	Numerous (29) failures after very limited service life in cast steel lugs (austenitic Mn); High replacement costs, downtime and production losses	Examined fracture face and microstructure features causing failure; Revealed very poor foundry practice/ inferior workmanship	Facilitated warranty settlement; contributed to future manufacturing and quality assurance improvement

The highest quality ore grades available for mining are declining, hence mining will have to process lower grade ores in the future. A finer grind size is needed for low-grade ores, which will lead to an increase of wear and thus greater costs in the future [7]. In Canada, on average, every ton of copper extracted produces more than 99 tons of waste material. The amount of gold extracted per ton of material excavated is even less. For example, the ores have to be milled down to ~20 μm in order to concentrate to 23% of copper (Cu) and 18g/ton of gold (Au) from the ores which originally contain 0.62% Cu and 0.95g/ton Au at the NewGold Afton Mine. The NRC mining materials wear and corrosion consortium is continuously providing unique service and knowledge to the mining industry to address the challenges. In addition to the laboratory-scale materials evaluation and analysis, the consortium is also repositioning roles to have a greater impact on the NRC's High Efficiency Mining (HEM) program by expanding research capabilities, using the consortium as a platform to bring more business opportunities, and collaborating with other international associations.

Conclusions

Material loss due to wear and corrosion is a well-known issue for the mining industries and the estimated cost was around C$15 billion in Canada in 2013. The NRC/Industry Mining Materials Wear and Corrosion Consortium, founded in 1996, has demonstrated a successful approach in achieving larger gains and faster progress by a more concerted collaboration. The expertise, the unique capabilities, and the materials database at NRC have helped the consortium members to reduce severe wear and corrosion damage, yielding cost reduction and profit growth of over C$100 million a year. The NRC Mining Materials Wear and Corrosion Consortium is continuously providing a unique service and is expanding capabilities to benefit more members in the future.

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