

Tribology in Mining

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Introduction

Mining is an age-old profession that is focused on the exploration of earth minerals for raw materials necessary for civilization. A classic mining operation encompasses three vital processes in order of extraction, materials handling and processing. Figure 1 shows an example of such an operation. Extraction of minerals, either from the surface or from underground mines, demands the use of a number of techniques like drilling, blasting, digging, etc. Once the minerals are extracted, they are transported to their processing unit using conveyors, haulage (for example, mining trucks) or rail transport system. The large chunks of minerals are broken into smaller sizes and into fine particles in the mineral processing unit. This is accomplished using a combination of techniques like grinding, jaw crushers, etc.

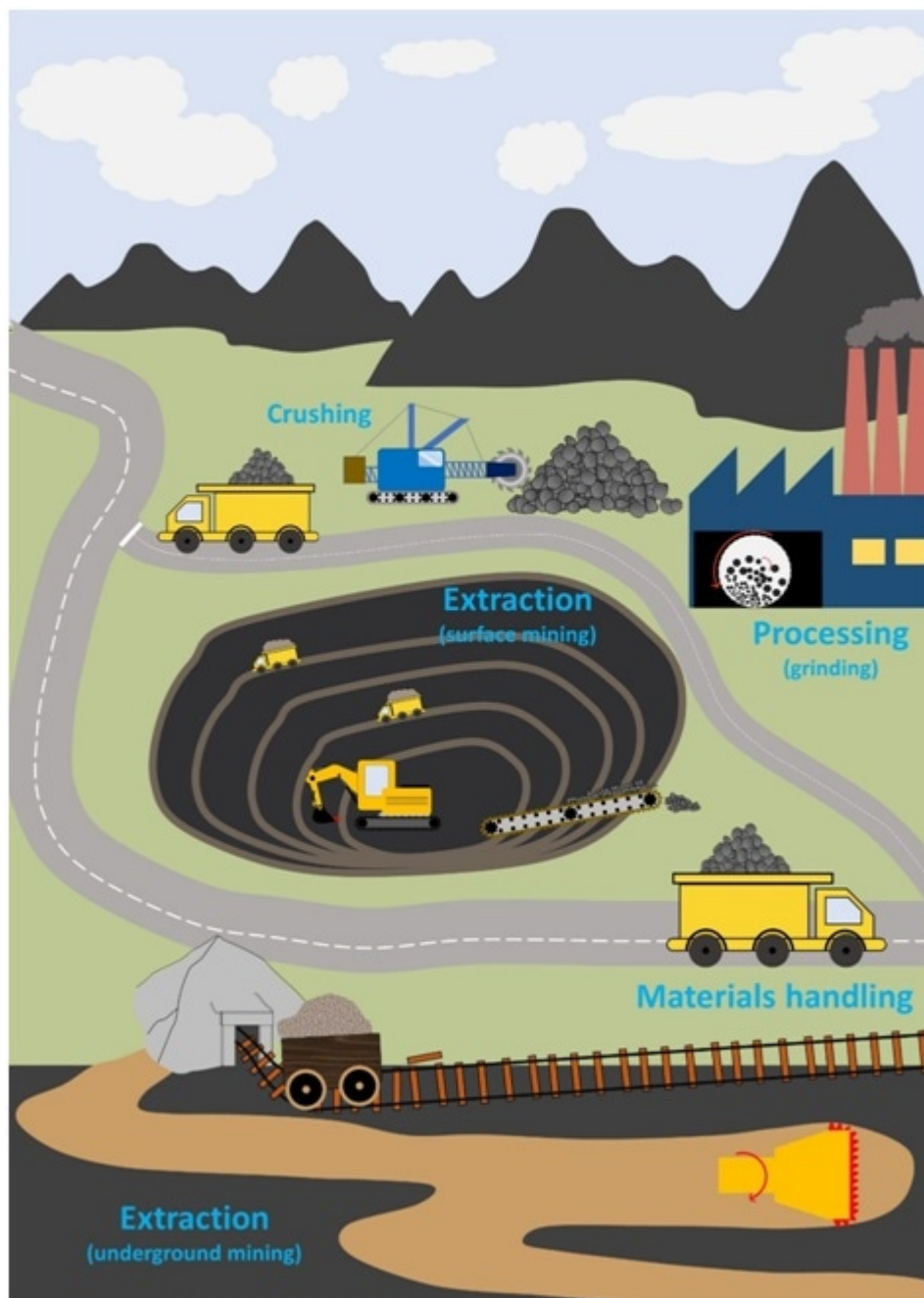


Figure 1. Illustration of typical mining operations: extraction, materials handling and processing.

Mining operations have progressed from the use of flint stones to diamond drills and labor-intensive activity to energy-intensive process. A recent study by Holmberg et. al. (Trib. Int. 115 (2017) 116–139) shows that mining operations account for 6.2% of the total global energy consumption. Electricity and diesel are the two major sources of energy for mining.

Among the three processes in mining operations, materials handling consumes more energy compared to extraction and material processing as shown in Figure 2. In mining, energy consumption can be due to friction and wear of materials used in mining

operations. Wear of materials is the main reason for equipment failure that increases the cost associated with procurement of the spare components and the downtime cost due to production loss. This monetary loss is used as a metric to account for the consumption of energy due to wear. However, friction, a direct representation of energy consumption, is the energy consumed to overcome the resistance to motion.

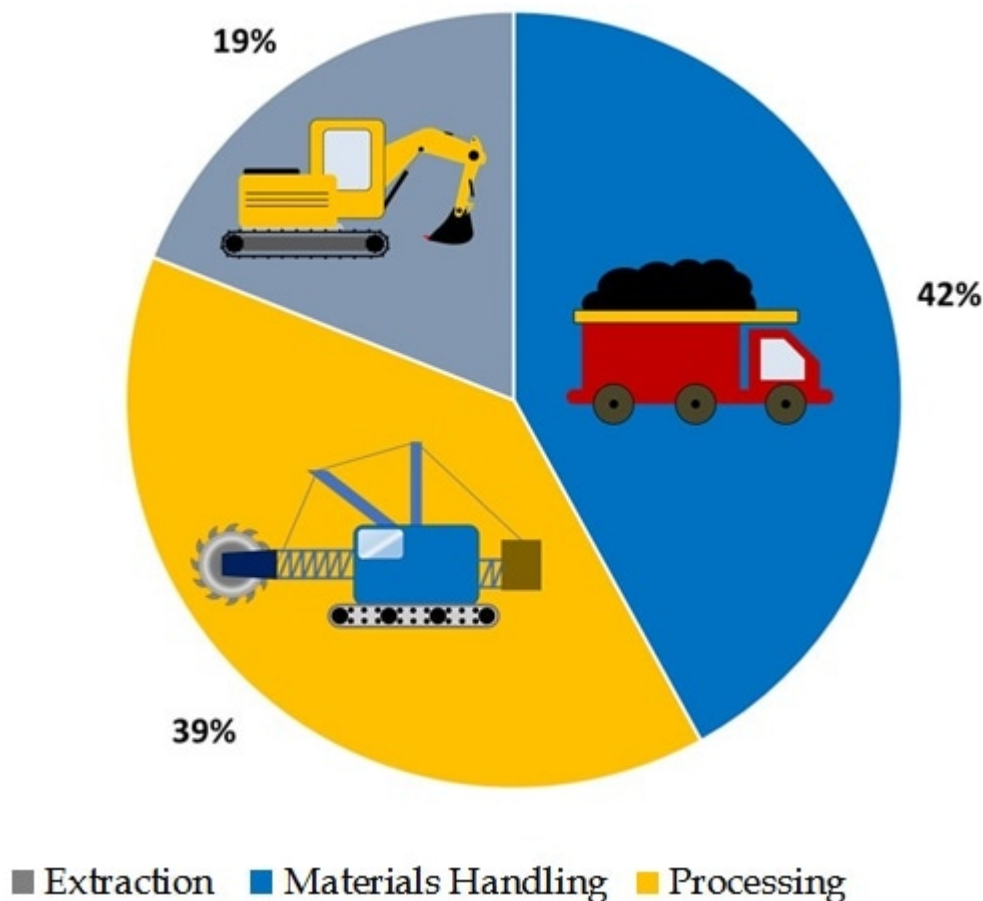


Figure 2. Energy consumption in mining industry.

On the whole, wear and friction during mining can release 2.7% of the total global CO₂ emission.

Figure 3 shows an example of friction and wear process during extraction, materials handling and material processing. Destruction to the materials used for digging or drilling are a result of abrasive, impact and erosive contact with the surface of the earth. Materials used in crushers encounter severe impact and abrasive contact with large chunks of minerals. Mining trucks, with lubricated engine components and other power transmission systems, used for materials handling face lubricated wear. The transportation of minerals is made through the slurry pipelines when the size of the particles is a few mm. During this process, slurry abrasion causes the damage of pipeline materials. Grinding balls, used in the ball milling process to generate fine particles, are subjected to impact, abrasion and

erosion contact with the minerals.

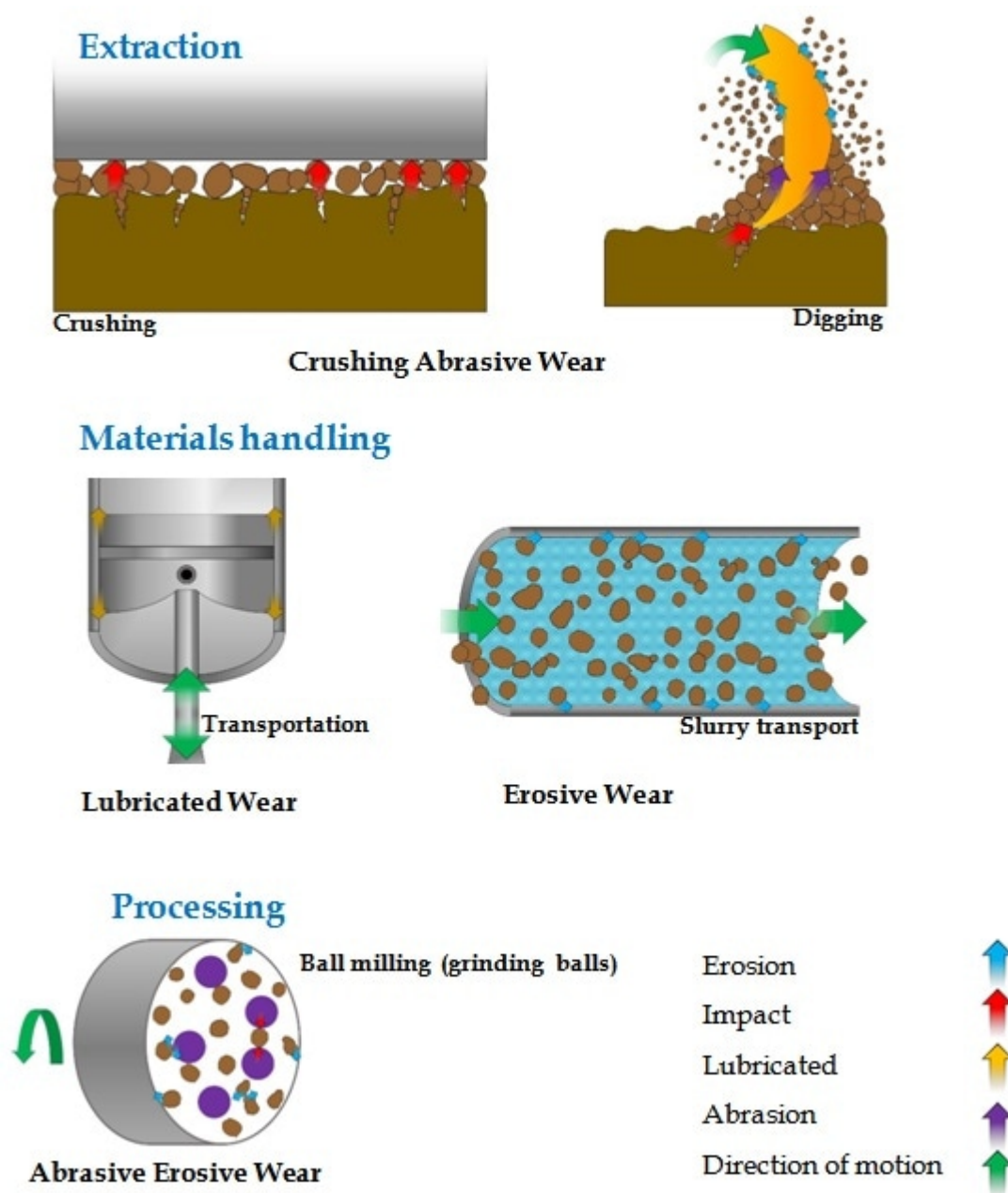


Figure 3. Dominating friction and wear mechanisms during extraction, materials handling and material processing in mining.

A number of methods could be employed to minimize friction and wear. A few examples include switching to low viscosity engine oils, polycrystalline diamond coating of the drill bits, etc.

As shown in Figure 4, a decrease in wear and friction of materials to be used in mines in 2025 is predicted compared to mines in 1990. Such a notable progress can be credited to developments in scientific research like tribology, analytical tools, material science, etc.

Our aim is to enable the scientific efforts focused on development of low wear and friction materials to decrease the consumption of energy and emission of CO₂ in mining.

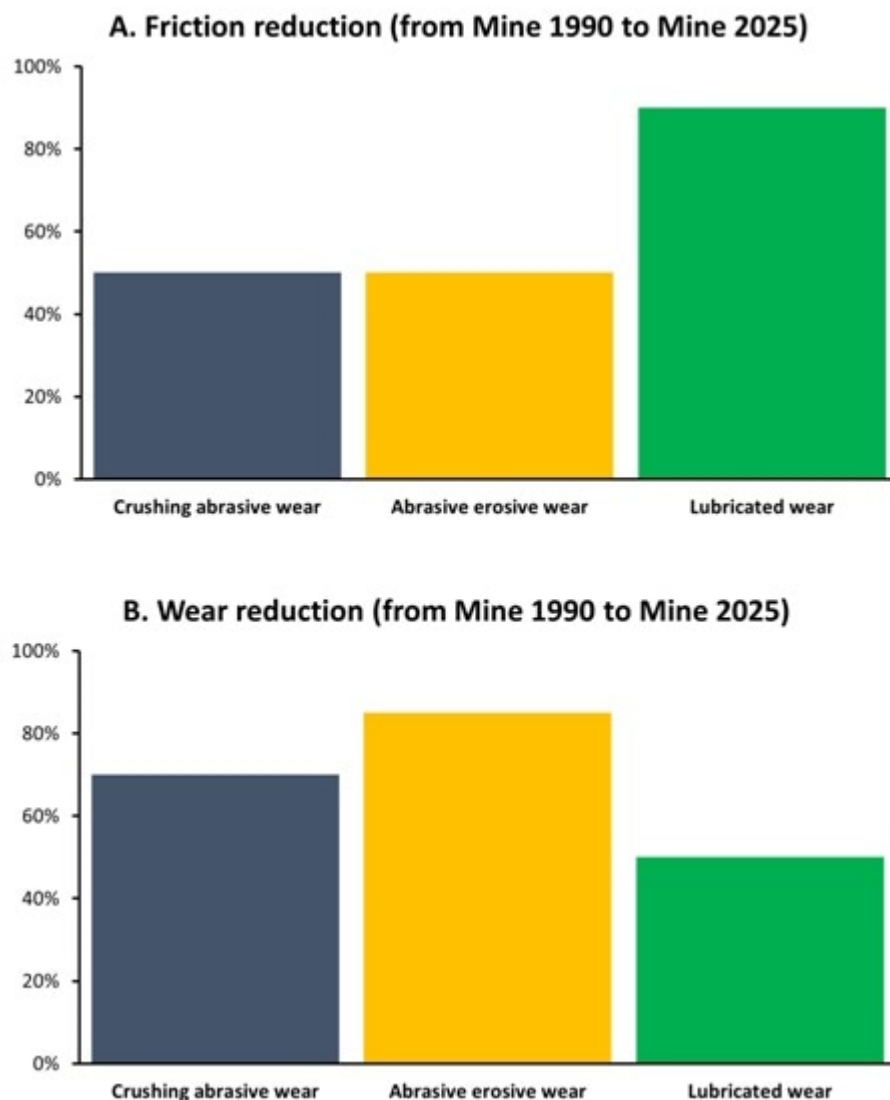


Figure 4. Estimated relative friction (A) and wear rate (B) reduction trends and possibilities in mining machines and equipment over the period 1990 to 2025 (from Mine 1990 to Mine 2025). ^[1]

Air Jet Erosion Tester (ASTM G76)

Ducom Air Jet Erosion Tester, shown in Figure 5, is used to calculate the erosion weight loss of materials, and analyze erosion resistant behavior of components used in energy and transportation industries.

In the mixing chamber, solid particles from the feeder unit and compressed air from the pneumatic air control unit are mixed. Compressed air transports the solid particles in the

steel tube, and it departs through the nozzle connected to the tube. The difference in the diameter of the tube (larger) and nozzle (smaller) produces an energy flux of particles that impacts the specimen.

The length of the tube is adequate to avoid any turbulence in the flow. Impact velocity of the particles is varied by altering the compressed air pressure that carries the solid particles. The speed of the motor in the powder feeder unit controls the discharge rate of the particles.

EROSIVE WEAR DURING DIGGING, GRINDING, ETC.

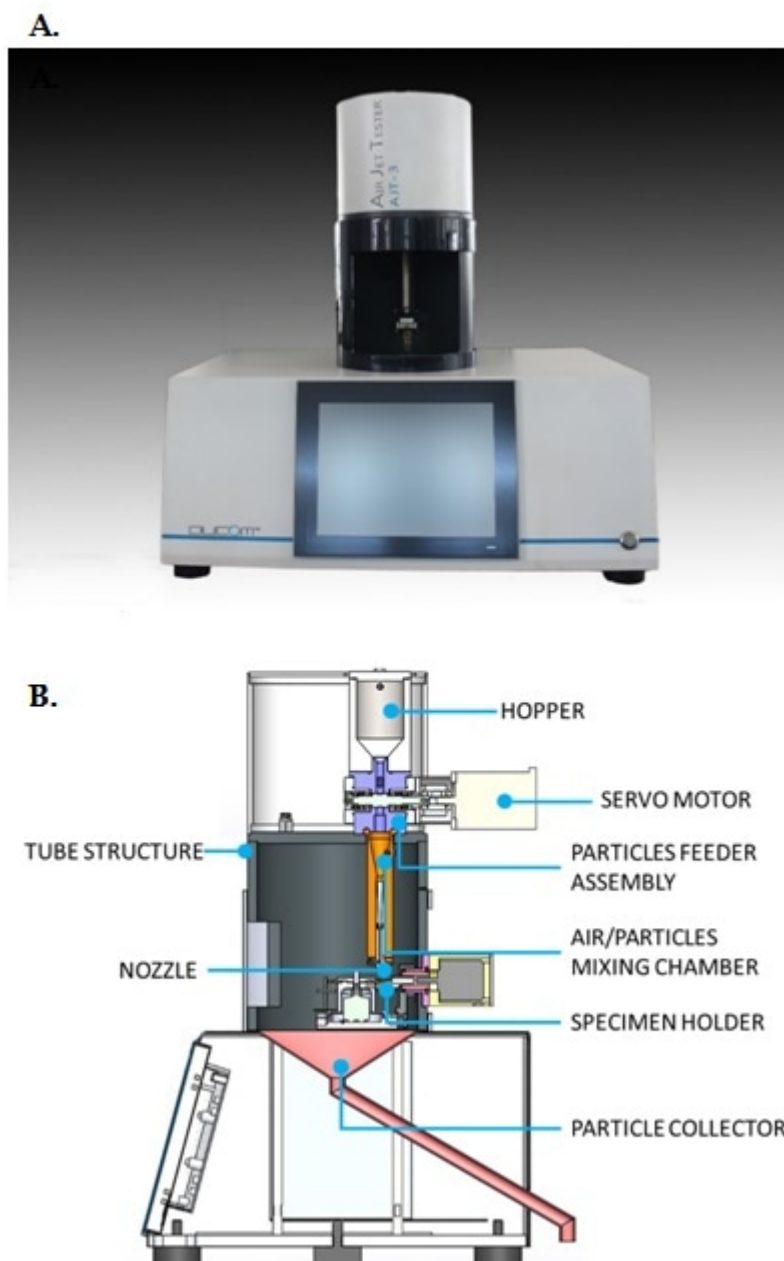


Figure 5. New design of Ducom Air Jet Erosion Tester (A) and the cut section (B).

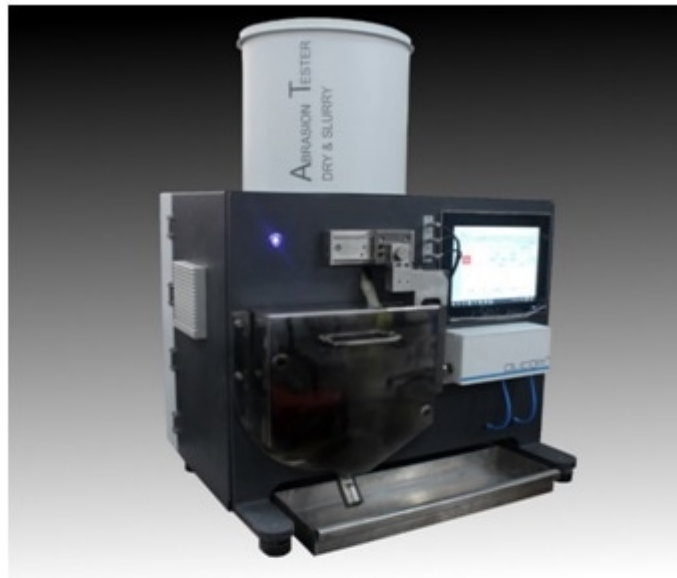
Dry and Slurry Abrasion Tester (ASTM G105, G65, B611)

Using Ducom Abrasion Tester, users test materials for their dry and slurry abrasion resistance properties in accordance with relevant standards, such as ASTM G65 G105 and B611. This system is acceptable for ranking materials used in mining.

The Abrasion Tester is designed such that a flat test sample is radially pressed against a wheel with a known force. A flow of dry abrasive particle can be directed at the contact between the flat sample and the rotating disk by means of a nozzle. A slurry chamber allows the testing of samples submerged in an abrasive solution. The test area is then immersed in wet abrasive media. The arrangement is such that the wheel carries the abrasive media between the sample and the wheel creating a scenario of three body wear using the slurry in the chamber.

ABRASIVE WEAR DURING GRINDING, SLURRY TRANSPORT, ETC.

A.



B.

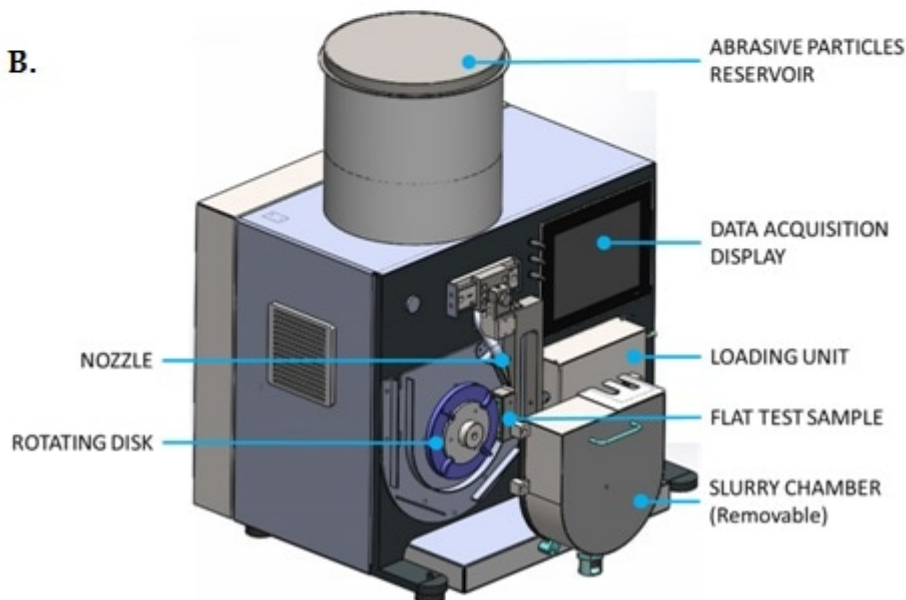


Figure 6. New design of Ducom Dry and Slurry Abrasion Tester (A) and the cut section (B).

Rotary Tribometer (ASTM G99)

Figure 7 shows a Ducom Rotary Tribometer, which is a workhorse of several tribology labs for real-time measurement and analysis of friction and wear behavior of materials in the form of ball/pin and disk specimens. This tribometer is used to create crushing abrasion friction and wear in dry or slurry medium. In this tribometer, the load, speed, temperature, impact cycles and motion are few important variables that can be measured and controlled.

Impact load cycles are computer controlled using a pneumatic load control unit. The disk speed profiles are controlled using a servo driven motor. During the test, the linear wear and friction force are achieved using a linear variable differential transducer and a button type load cell, respectively. The friction and wear of materials can be measured in an abrasive slurry mixture in this tribometer. This is a novel design where the position of the disk and its motion are horizontal, which is shown in Figure 7A, whereas in a standard tribometer the position of the disk and its motion is vertical, as shown in Figure 7B. Such a horizontal position of the disk prevents the leakage of the slurry into the spindle assembly.

IMPACT ABRASIVE WEAR DURING JAW CRUSHING, GRINDING, ETC.

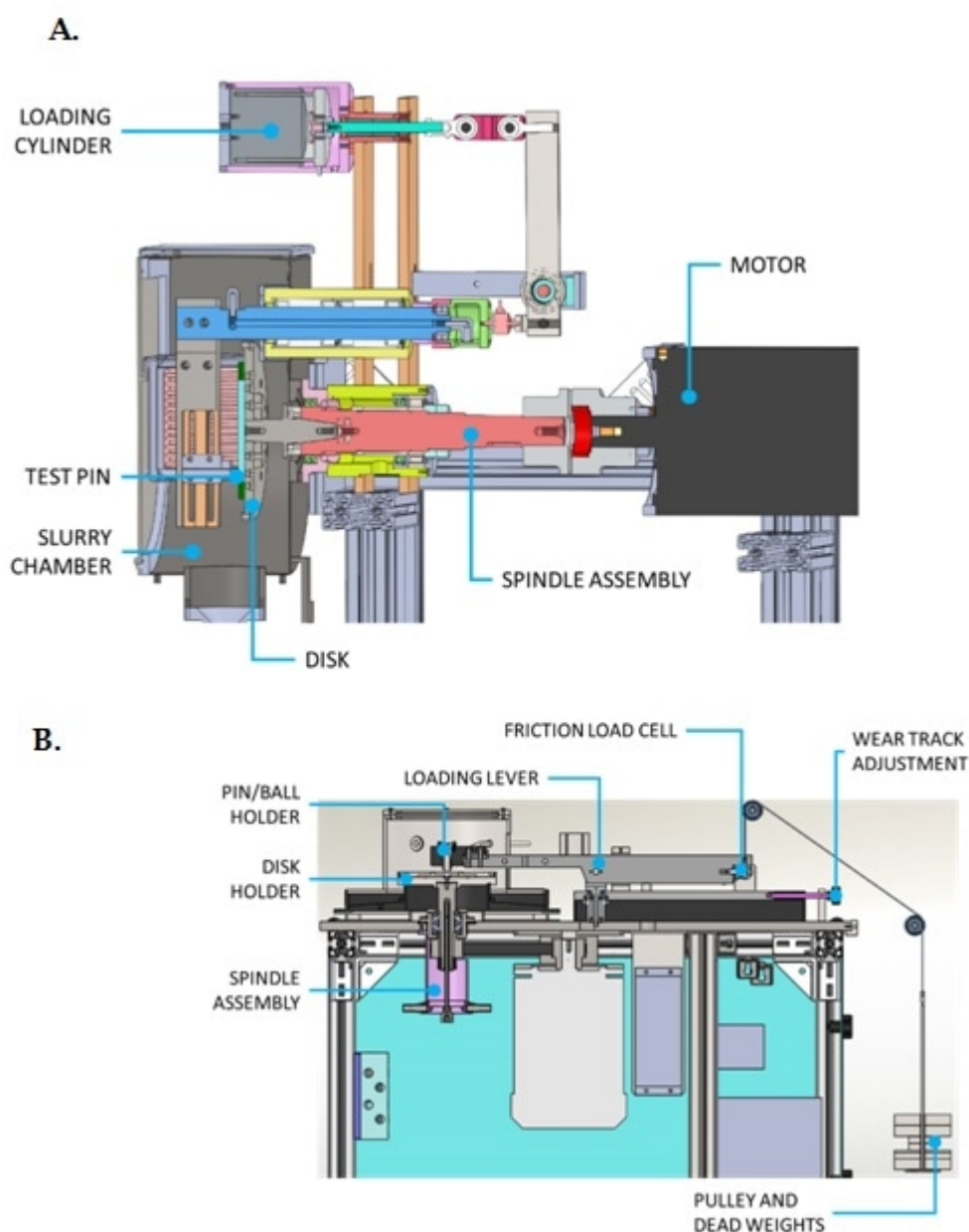


Figure 7. Cut section view of the Ducom Rotary Tribometer – Horizontal set up (A) and

Ducom Customer Feedback: Donhad Pty - Australia

Improving Grinding Media Efficiency

Ducom Rotary Tribometer enabled laboratory test setup that can replicate the friction and wear behavior of grinding balls used in mineral processing. Using the Ducom Rotary Tribometer, Donhad from Australia is developing the low wear grinding balls used in mineral processing.

Customer Challenge

According to Amir – Business Manager from Donhad, a big portion of mines consumable cost is the grinding media cost. Therefore, it is very important to offer a product to the customer that has better wear life thereby reducing their cash cost. Based on the size of the mineral processing plant, a 5% improvement in wear rate of grinding media could potentially save millions of dollars per year.

At mineral processing plants, measuring the small changes in wear rate of grinding media due to a change in its material properties is ordinarily too difficult. This is because of lot of noise and variation inherent in the process. Hence, it is crucial to use a laboratory test setup that can exactly duplicate the criteria used in mineral processing.

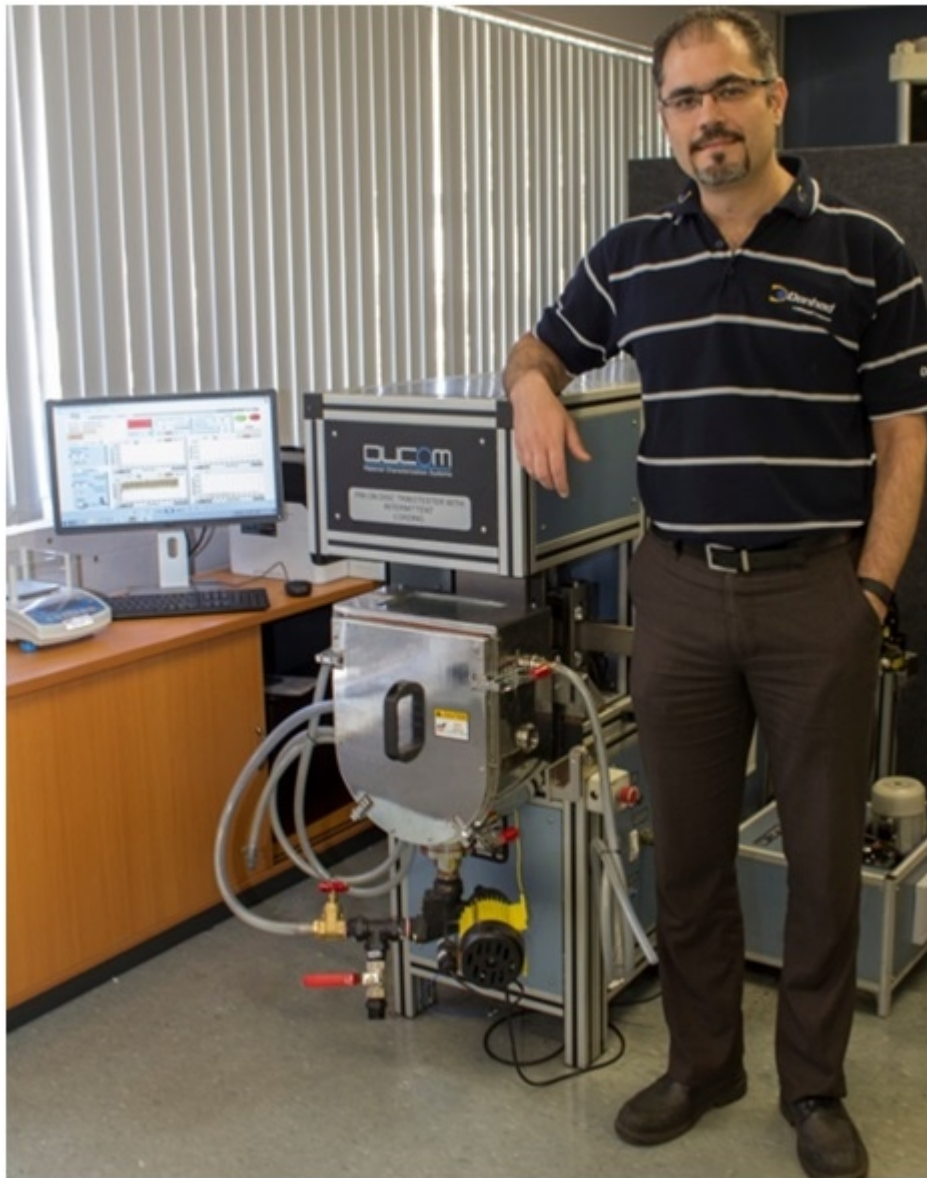


Figure 8. Mr. Amir Bahri, Business Manager, Donhad in Australia (Ducom Rotary Tribometer in the background).

Ducom Solution

The chief process parameters that affect the life of grinding media are impact load and its frequency, temperature and sliding velocity. For Donhad, it was essential that Ducom can control and measure these variables at high precision. For this project, they chose the basic design platform of Ducom Rotary Tribometer with added major features like automated sliding speed control, automated loading unit (fixed or impact load), abrasive chamber and chamber heating. Pin and disk sample holders were designed to match various grinding media types and sizes.

Customer Benefits

The impact load and speed profiles noticed during the mineral processing are reproduced in the lab. The process parameters are controlled at $\pm 1\%$ of the maximum value and have a good repeatability. Ducom Rotary Tribometer is able to detect minor changes in the hardness of grinding balls by measuring its friction and wear response. In conclusion, Amir mentions that the Ducom Rotary Tribometer helps them to find a correlation with the field wear, and it saves cost and time in assessing new products performance in terms of wear life.

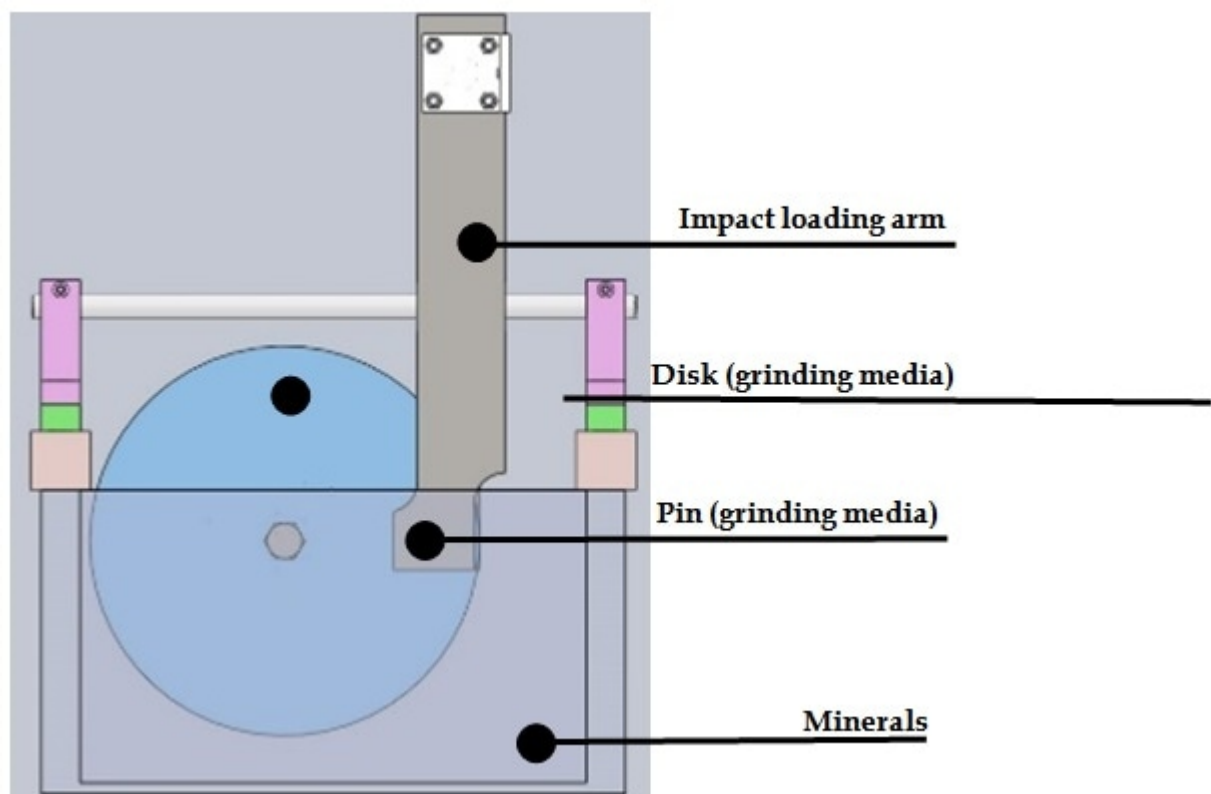


Figure 9. Ducom Rotary Tribometer designed for mining companies.



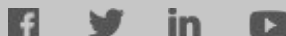
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Ducom

**Address**

820 Davis St. STE 405
Evanston
Illinois, IL60201
United States

Phone: +1 (847) 737 1590**Email:** info@ducom.com[Visit Website](#)

Ducom Instruments leads the way in designing and manufacturing advanced materials testing instruments specializing in tribology. Through the application and implementation of cutting-edge technology as well as strong design principles to its products, Ducom focusses on providing customers with excellent ownership experiences.

Ducom instruments use components that are manufactured in an AS9100:2009 certified “aerospace grade” manufacturing facility for excellent quality.

Our instruments are operational and recognizable all over the world. Leading Research labs working on cutting edge technology development which requires advanced and highly configurable test systems to standardized quality control requirements which rely on highly repeatable systems to accurately monitor product quality test instruments by Ducom.

Primary Activity

Material Manufacturer

Manufacturer of test instruments for mechanical characterization