

COMMINUTION TESTS

SGS MINERALS SERVICES (MINERALS METALLURGY)

OVERVIEW

SGS Lakefield Orestest Pty Ltd (SGS) was founded in 1993 and has since developed into a major metallurgical services organisation located in a purpose-built laboratory in Perth, Western Australia.

The laboratory is dedicated to providing high quality metallurgical testing services to the mining industry, including but not limited to:

- Gold ores
- Nickel laterites
- Base metal ores
- Iron ore
- Mineral sands
- PGM ores
- Rare-earths and other exotics
- Diamond ores
- Environmental services



SGS provides a comprehensive range of test work capabilities including bacterial leaching, crushing, screening, grinding, ultra fine grinding, gravity, magnetic & electrostatic separation, solvent extraction, electrowinning, flotation, pressure leaching, pressure oxidation, pressure acid leach and cyanide speciation. Pre-feasibility studies, on-site diagnostic metallurgical services, environmental testing and analytical services are also included in our range of capabilities.

CAPABILITIES

SGS offers a comprehensive range of comminution tests ranging from standard Bond rod and ball mill work index determinations to SAG Performance Index (SPI) tests. A brief description of tests available follows:

CRUSHING WORK INDEX TEST

The test determines the Bond Crushing Work Index which can be used with Bond's Third Theory of comminution to calculate the net power requirements for sizing crushers. It can also be used to determine the required open size settings (jaw crushers and gyratory crushers) or closed sized settings (cone crushers) for a given product size.

The impact apparatus consists of two pendulum mounted hammers mounted on two wheels so as to strike equal blows simultaneously on opposite sides of each rock specimen. The height that the pendulum is raised is increased until the energy is sufficient to break the specimen.

All results obtained are ranked against SGS' AR McPherson database to facilitate a comparison with other ores.

The test is conducted on at least 20 pieces of -76 + 51 mm material.

JK DROP WEIGHT TEST

The JKTech Drop-Weight Test developed at the Julius Kruttschnitt Mineral Research Centre, measures the appearance function of the ore for five sized fractions in the range of 13 to 63 mm, at various energy inputs (0.1 to 2.5 kWh/t). The results are subsequently reduced to two parameters: A and b. The apparatus consists of a system for dropping a variable weight onto different size rock specimens from various heights. As part of the procedure the abrasion characteristic of the sample (t_a) is also determined using a tumbling test.

These ore specific parameters can be used in grinding circuit modeling and simulation using the JKSimMet software package. Combinations of crushing, AG or SAG grinding, classification, and secondary grinding can be modeled and simulated. Crushing energy requirements can be estimated from the drop-weight test, and AG/SAG energy requirements can be estimated from the simulation.

Results can be used in the simulation of operating plants to test changes in ore types, classification sizes, ore feed size distribution, ball load, grate apertures, use of pebble crushers, ect. Simulation can also be used in new circuit design to examine various circuit configurations and to refine equipment selection and performance.

The test procedure requires 65 kg of material, which is prepared by the testing facility, to generate 30 to 90 particles in five size fractions.

SAG MILL COMMINUTION TEST (SMC)

The SMC test is an abbreviated, cheaper version of the drop-weight test, which can be performed on small rocks or drill cores. Cores are cut into $\frac{1}{4}$ cylinders using a diamond saw and the test is subsequently performed as per the standard drop weight test procedure, except that only one size fraction is tested. The test generates the A and b parameters, which are used in the JKSimMet simulations, and a drop-weight index in kWh/t. The test uses a single (and finer) size fraction, as well as a smaller number of specimens (100) which limits its accuracy. Normally, the main ore zone (s) in the deposit is tested using the full procedure to calibrate the SMC test, which can then be used to generate detailed mapping information at lower costs on localized samples, providing they have comparable geological characteristics.

The test procedure requires 100 rocks (minimum 60), or quarter core 'cubes' in any given size fraction of the drop-weight test procedure. For the standard size (27 to 32 mm), this can be obtained by stage-crushing approximately 20 kg to passing 32 mm. A lower sample mass (5 kg) is often sufficient, if the test is performed on smaller rocks.



ABRASION INDEX TEST

The Abrasion Index can be used to determine steel media and liner wear in crushers, rod mills, and ball mills. The Abrasion Index test was developed by Allis-Chalmers using a method and apparatus used by the Pennsylvania Crusher Division of Bath Iron Works Corp. The equipment consists of a rotating drum, into which dry ore pieces (- 19 + 12.5 mm) with an impact paddle mounted on a centre shaft rotating at a higher speed than the drum. The paddle is made of a standard alloy steel hardened to 500 Brinell. The abrasion index is determined from the weight loss of the paddle under standard operating conditions.



All results obtained are ranked against the SGS' AR McPherson database to facilitate a comparison against other ores.

The test is conducted on 1.6 kg of - 19 + 12.5 mm material which can normally be obtained by crushing 5 kg of ore to minus 19 mm.

BOND ROD MILL WORK INDEX TEST

The Bond Rod Mill Work Index is used in conjunction with Bond's Third Theory of Comminution to calculate net energy requirements for sizing rod mills. The test was originally developed in the mid 1930's by F.C. Bond and though it was altered in preceding years it has essentially remained unaltered since 1961.



The test is conducted in a 305 mm diameter by 610 mm long (inside dimensions) horizontal axis mill. There are eight rods all 530 mm long which weigh a total of 33.38 kg. Two rods are 44.5 mm in diameter and six rods are 38 mm in diameter.

All results obtained are ranked against SGS' AR McPherson database to facilitate a comparison with other ores.

The test is conducted on 15 kg of - 12.5 mm ore and can be performed on closing screen sizes ranging from 4 mm to 250 µm. The standard closing screen size is 1.18 mm.

BOND BALL MILL WORK INDEX TEST

The Bond Ball Mill Work Index is used in conjunction with Bond's Third Theory of Comminution to calculate grinding net energy requirements. The test was originally developed in the mid 1930's by F.C. Bond and though it was altered in preceding years it has essentially remained unaltered since 1961.

The test is conducted in a 305 mm diameter by 278 mm long (inside dimensions) horizontal axis mill with rounded corners and smooth lining.



The ball charge consists of 285 balls of different sizes weighing 20.125 kg.

All results obtained are compared to SGS' AR McPherson database to obtain a comparison against other ores

The test is conducted on 10 kg of - 3.35 mm ore and can be performed on closing screen sizes ranging from 500 µm to 38 µm. The standard closing screen size is 106 µm.

MINNOVEX SPI TEST

This test determines the MinnovEX SAG Power Index. It is used to determine ore body hardness profiles for operating or potential mines. The SPI values are used to predict throughputs for SAG/AG mills and in the determination of power requirements for such mills in potential mines using the Minnovex CEET program. The test is a batch test, run with 2 kg of ore in a standard 10 cm diameter by 30 cm long SAG mill, and it measures the time (in minutes) required to grind a sample from 80% passing 12.5 mm to 80% passing 1.70 mm.

The test is run in conjunction with a Minnovex crusher index (included in the SPI test) that uses the breakage characteristics during sample preparation to minus 12.5 mm to predict the SAG mill feed size using the CEET program.

The test is conducted on 10 kg of - 12.5 mm ore.

MINNOVEX 'MODBOND' GRINDABILITY TEST

Similar to a comparative work index, this test is an open circuit dry batch grindability test run in the standard Bond ball mill for a set time and can be used at closing screen sizes from 250 µm to 75 µm (normally 150 µm). The test requires calibration against the standard Bond ball mill index test to estimate the work index. It is used to show the ore body hardness profile and to predict throughput in a ball mill circuit.

The test is conducted on 1.2 kg of - 12.5 mm ore.

ADDITIONAL COMMINUTION AND PHYSICAL TESTS

Other tests offered include:

- Allis Chalmers Media Competency Test
- Allis Chalmers High Energy Impact Test
- Amdel-Orway Advanced Media Competency Test
- Brinell Indentation Microhardness
- Dorry Hardness Test
- Hardgrove Grindability Test
- JK Pendulum Test
- Kilborn Pebble Competency Test
- Knoop Indentation Microhardness
- Limestone Grindability Test
- Los Angeles Abrasion Test
- MacPherson Autogenous Grindability Test
- Miller Abrasivity Test
- Moh's Hardness
- Point-Load Test
- Static Pressure Test



- Thompson Test
- Unconfined (Unaxial) Compression Test
- Vickers Indentation Microhardness
- Volumetric Hardgrove Grindability Test

WORLDWIDE COMMINUTION CONSULTING AND MODELLING CAPABILITIES

Introduction

SGS Minerals Services supports the mining, minerals, and chemical industries in the design and operation of efficient crushing and grinding circuits using both power and model-based methods. We design circuits and provide operating advice to maximize milling efficiency, considering both steel and power consumption. Our practical experience also ensures that we recommend circuit configurations that offer ease of operation and maximum flexibility.

Our worldwide network of metallurgical testing facilities can provide bench scale testing and limited piloting. The most extensive piloting facilities are located in Canada. Our comminution experts travel the world as required, providing support to comminution testwork programs.

Most comminution testwork is conducted in-house at our facilities in Canada, Chile, Australia and South Africa. We also conduct comminution testing and piloting programs at remote client sites.

SGS Minerals Services' engineers have experience in operating SAG mill plants and have operated over 500 pilot-plant SAG circuits. This hands-on experience fosters a practical view of the design and operation of grinding circuits.

We have experience in many techniques, including the model-based approach and the empirical power-based approach, using the Bond and autogenous grindability tests. All data is analysed and related to previous testing results. We compliment the JKTech models with mass-balancing, using the Bilmat program. We suggest that the most robust results are obtained when more than one approach to grinding circuit testing and design is used.

PILOT TESTING

For many projects, due to the size, complexity, or desire for absolute minimum start-up time or maximum efficiencies, there is no substitute for pilot testing. The best pilot program is based on thorough bench-scale testing and circuit simulation. Comminution pilot-plant capabilities at our Canadian operations include a 1.68 m diameter, fully instrumented Nordberg autogenous mill, and a wide variety of rod and ball mills. Circuit configurations, including AG, SAG, ABC or SABC, are evaluated easily.

The circuit employs an integrated Bailey Distributive Control System (DCS) for monitoring plant conditions. Feed rate, mill speed, power, mill load, particle size distribution and other data are updated, trended, and recorded automatically for later retrieval. This full-instrumented pilot plant allows circuit changes to be brought to steady-state more rapidly and avoids wasted pilot plant time. We have completed more than 150 pilot plant programs.

A typical test program involves investigation of the response of the ore to fully autogenous grinding and SAG mill primary grinding. In the SAG mill testwork steel addition, SAG product classification size and ore feed size distribution would be varied. If necessary, pebble crushing or mill speed could also be investigated.

Tests are evaluated on the basis of feed rate, power consumption and product size analysis. Unless single-stage autogenous grinding is considered, it is recommended that the secondary ball or pebble mill circuit be operated in all



tests to provide overall power data and to allow adjustment of the secondary mill conditions to obtain the desired fineness of grind.

PROCESS MODELLING SIMULATION

Simulation Studies Applications

We have extensive experience with computer simulation and routinely use it as a tool to reduce risk in comminution investigations. It can evaluate or quantify:

- Troubleshooting/alternative circuits configurations
- Flowsheet development/equipment sizing options
- Pilot-plant support
- Simulate viability
- Expansions
- Process changes
- Compare observed with predicted behaviors
- Introduce impact of deviations and predict effects
- Rigorously compare process alternatives
- Quantify differences and efficiencies, bearing in mind cost implications

Investigative Capabilities

- AG/SAG circuit operation
- Feed hardness (Drop-Weight Test), feed PSA, feed rate, mill size, mill speed, ball charge, ball size, grate or pebble port size and configuration, classification type/size
- Ball Mill circuit operation
- Feed hardness (Bond Tests), mill size, mill speed, ball charge, ball size, cyclone geometry, cyclone operation (inlet, apex, vortex, feed density, pressure, number)
- Hydrocyclone operation
- Screen operation
- Crusher operation

Simulation Studies Deliverables

- Material balance: flow and water rates, percent solids, and PSA
- Mill and motor sizing
- Circuit performance
- Recommended operating conditions



Simulation Studies for Pilot-Plant Applications

- Support pilot-plant test program design.
- Pre pilot-plant simulations narrow the scope of testwork required, and hence the quantity of ore required and cost.
- Predict the material balance and provide estimated feed and water rates in advance, producing stability sooner.
- Gives a base for scale-up for mill size, ball change, ball size, mill speed, which may be different in the full-size plant.

ON – SITE PROGRAMS

For on-site programs, with operating plants, our recommended approach is to send a senior engineer to the site to discuss client objectives and constraints, as well as to perform a survey. The analysis of the data will determine where the plant could increase its performance ability and the simulation will identify how the plant may be improved.

EXPERIENCE RECORD

JK SimMet Mineral Processing Computer Simulation Package.

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