Procemin·GEOMET 2024 | 20th International Conference on Mineral Processing and Geometallurgy

Advancing Orebody Knowledge with High-Resolution Rock Strength Measurement using the Minpraxis Tester

Gonzalo Pizarro[1], Stefan Nadolski[2] and Bern Klein[1]

1. *Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Canada*
2. *Minpraxis Solutions, Canada*

ABSTRACT

The Minpraxis Tester (MPT) is a compression-breakage test device that treats half-core samples continuously length-wise, providing a high degree of rock characterization in comparison to conventional methods. Furthermore, it is able to extract this information while operating as a crusher when used in a conventional assay preparation workflow. This expands the characterized volume of a rock mass to include samples that were recovered for assay purposes, in other words resource core, and would otherwise not be measured with industry-standard methods. The additional resolution on a local-scale (order of 1cm) and the ability to test samples while preparing them for assay results in a significant increase (order of 1,000 times more) characterization data over conventional methods.

Outputs of the device include geotechnical and geo-metallurgical parameters, such as point load Index IS50 and DropWeight-type indices, which are measured while capturing the variability of strength within core sections.

The MPT device can also be used to test lump samples, which provides the capability to test core pieces that have broken apart during the drilling process as well as the ability to rapidly test lump pieces to determine their crushability and grindability.

INTRODUCTION

The mining industry is challenged by having only 20 percent of mining operations perform within estimates outlined in feasibility studies (Dussud et al, 2019). A substantial proportion of underperforming mining operations trace back their failures to a lack of orebody knowledge. Orebody knowledge is fundamental to the design and operation of mining projects by providing valuable information for geological, mining, metallurgical, environmental, and economic decisions (Lakshmanan & Gorain, 2019 and Jackson, 2017). Sample and data sources feeding into orebody knowledge are usually obtained from testing and analyses of drill core, geological mapping, and geophysical/chemical surveys.

The trend in the industry towards developing spatially predictive 3D block models, which incorporate geotechnical and geo-metallurgical parameters, necessitates the use of sample characterization methods that can generate large volumes of data with appropriate composite sizes, unit costs, and turnaround times. The Minpraxis Tester (MPT) was developed to meet the demand for low-cost geotechnical and geo-metallurgical tests that can be applied to small sample volumes in large quantities, such as resource core (Nadolski, 2019 and Nadolski, 2020). The MPT can be used as a crusher in a typical assay preparation workflow while providing a high-resolution measurement of sample compressive strength. In the case of processing half-core, samples are processed lengthwise at a local-scale resolution in the order of 1cm. The MPT device can also be used to test individual lump samples, which provides the capability to test core pieces that have broken apart during the drilling process as well as the ability to rapidly test lump pieces, such as those from grade control samples. Over-all, a substantial increase in strength information is achieved for a rock mass: continuous high-resolution strength measurement and measurement of resource samples collected for metal assay (which would otherwise not be tested for strength and hardness characterization purposes).



Figure 1 MPT-II prototype at ALS laboratories (for a pilot) with automated laser-based sample size measurement

The latest full-scale prototype of the Minpraxis Tester, referred to as MPT-II, is shown in Figure 1. Key distinguishing features of the MPT are its high-resolution force sensor, large drivetrain allowing for controlled crushing, roller position sensors, instrumented feeder tubes for automated size measurement, high (40,000 Hz) data sampling rate and sensors for real-time gap measurement. A hydraulic system is used to apply compressive forces to samples as they are being drawn in between the rolls, while the high-resolution force sensors measures the resistance of the sample to the force being applied. The hydraulic system was specified to ensure that the pressing force is sufficiently high to avoid gap expansion during sample processing. Roll gap sensors are used to confirm that the operational gap has not changed, however their primary purpose is to aid in gap adjustment for machine setup.

METHODOLOGY

Two testing methods using the MPT will be described, the results from multiple validations test work over the last few years will be presented.

MPT Half-Core Method

MPT half-core tests is aimed at predicting PLT, UCS and JK DropWeight Index (DWI). For this method:

- Each individual half-core piece is tested, and the force responses are recorded.
- Machine responses are measured along the half-core and adjusted to a point load-type IS50 value based on the thickness of the sample (Şahin et al., 2020)
    - The instrumented core feeder tube measures the thickness and length of samples as they are fed to the MPT. In this way, variations in thickness can be taken into account for IS50 estimates.
- The signal recorded is process and sliced into 1 cm slices that then are combined and composited based on the target comparative testing. Figure 2 shows an example of the force reading for MPT Half-core test.

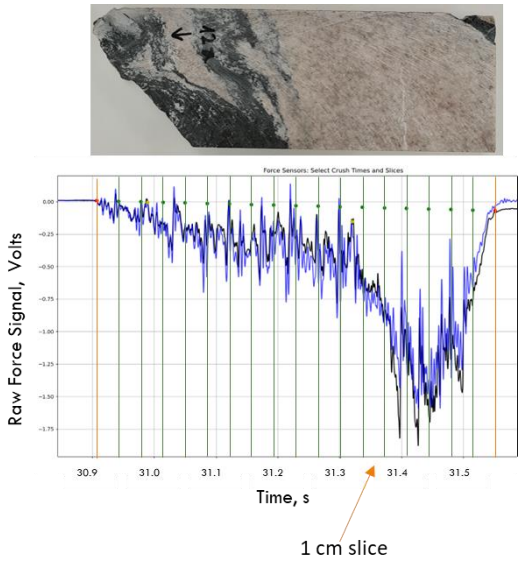
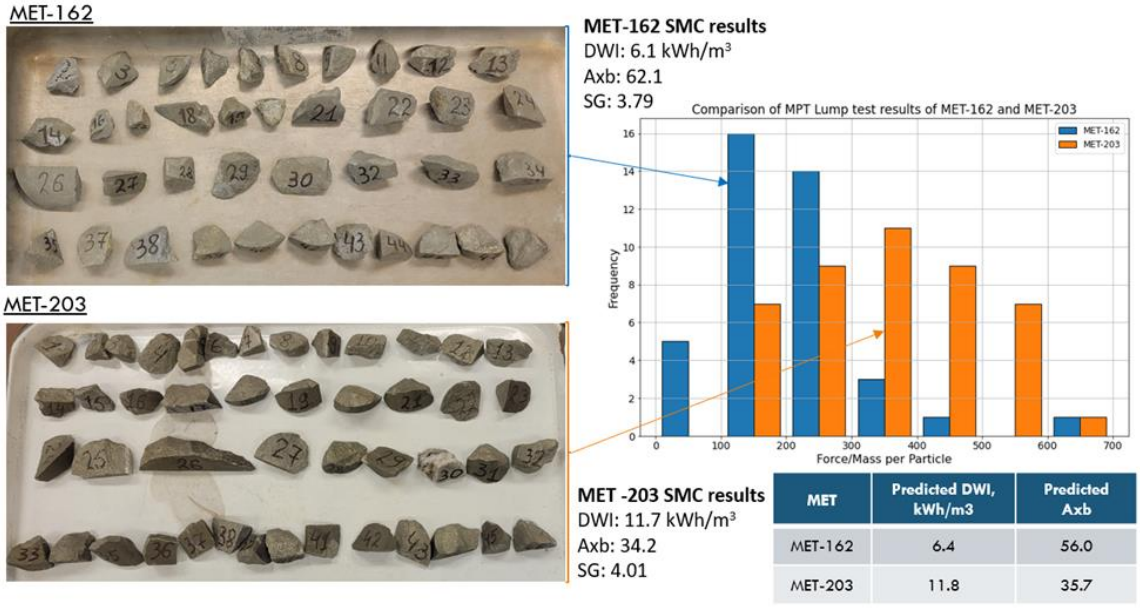


Figure 2 Example of force readings from the Minpraxis Tester for a half-core sample.

MPT Lump method

To investigate the applicability of the MPT for rapid testing of lump samples, such as ore control samples, focused test work has been carried out on samples from over 20 deposits. The current lump test methodology involves sieving of samples into narrow size fractions ranging from -9.5, +8 mm to -31.5, +26.5 mm. Each test uses 40 particles, tested individually, at the same machine settings for gap and roll speed. Product size distributions are not measured. Since each rock response is measured the distribution of hardness within the 40-particle set is obtained as shown in Figure 3.



MET	Predicted DWI, kWh/m3	Predicted Axb
MET-162	6.4	56.0
MET-203	11.8	35.7

Figure 3 Capturing the variability of particle Strength within samples.

Comparative Testing

- Uniaxial Compressive Strength (UCS) testing was carried out using an instrumented hydraulic press as per ASTM standards (2017) with four strain gauges connected to a strain gauge module and data acquisition system.
- Point load testing (PLT) was carried out per ASTM (2017) standards. Both diametral and axial testing was conducted. To normalize the Point Load strength results to an IS50 value (representing the diametral Point Load strength of a 50 mm diameter drill core sample), the IS50 equations involving correction factors, as published in ASTM D5731-08 (2017), were used.
- Indirect tensile tests (Brazilian Test) were carried out using the ISRM (2017) test method with curved platens and an instrumented hydraulic press.
- SMC DWI and Axb: Developed by Morrell, 2004 to help predict AG/SAG mill performance where limited quantities of rock samples are available. Originally developed to use quartered core but whole core, half core and lump material can also be used. The test uses the same JKMRC drop weight equipment and is based on the correlation between Drop Weight Index (DWi) with the A and b parameters. (Morrell, 2004)
- SAG grindability index (SGI): Measures ore hardness and grindability for SAG (Semi-Autogenous Grinding) mills, measured in minutes of grind time.

Sample Description

The focus on this paper will be the validation test work which was done for a Volcanogenic Massive Sulfide (VMS) deposit. Approximately 550 metres of half-core sample was used for the test program, which showed good correlations between measured and MPT-predicted IS50 and DWI. Product of the MPT half-core test were sieved and SMC and MPT lump test were carried out using -22.4+19mm particles.

RESULTS AND DISCUSSION

The MPT results for the half-core and Lump test will be presented.

MPT Half-core Results

For each of the 51 composites of ~11 meters, 20 Half-core PLT (Şahin et al., 2020) were conducted. Figure 4 shows the MPT IS50 prediction versus the average PLT following the ASTM standards achieving results within 15 %, Box plot of the results per piece versus the PLT for each of the composites are presented.

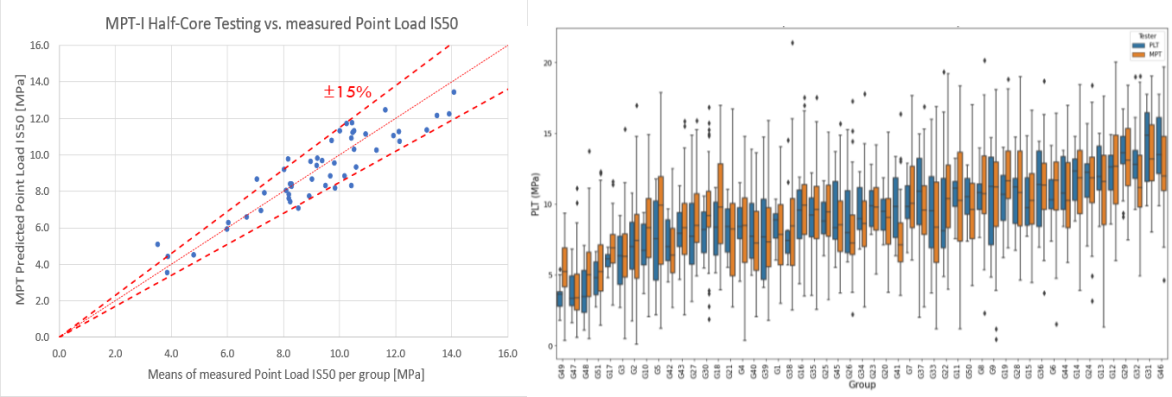


Figure 4 a) Comparison of MPT predicted and measured Point Load IS50 values for 51 geo groups. b) Box Plot comparison of MPT Predicted and measured Point Load IS50 values (blue PLT, orange MPT).

Additional geotechnical testing has been conducted with the focus on expanding the database to multiple ore deposits and validate the results in comparison with UCS and Brazilian test, due to the geometallurgical focus of this conference, we will focus on results relevant for characterization with respect to comminution.

MPT half-core test results were also used to build predictive models for DWI and Axb. The models still achieve results within 15 % for sample that would normally not be tested with traditional methods. Is important to consider the difference in size of a half-core HQ core to a particle -22.4+19mm used for the SMC testing.

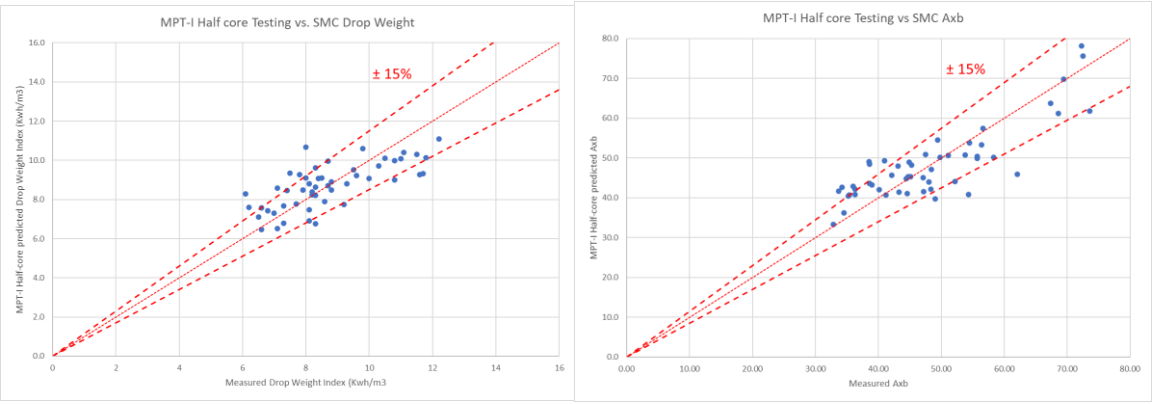


Figure 5 Comparison of MPT half-core outputs and measured DropWeight Index (left) and DropWeight Axb (right) values for 51 geo groups

Traditional approaches are characterized to be expensive and time-consuming, limiting the data volume and spatial variability knowledge, with implications during block modeling, design and planning. The MPT outputs also provide the variability in strength for the ~11 metre continuous sections. Due to the resolution of MPT measurements, well correlated DropWeight predictions can

be compiled to a finer interval size, as used for resource core assay composites, (e.g. 1 meter) to support integration with multivariate geostatistical methods for geometallurgical block modeling.

MPT Lump Results

After the half-core samples were tested with the MPT, the products were sieved and the -22.4 +19mm size fraction were used to conduct SMC and MPT Lump tests. The MPT as shown in Figure *3* captures the variability of hardness within the sample and takes less than 1 hour to complete. MPT Lump test results in relation to measured SMC DWI and SMC Axb are shown in Figure 6 achieving results within 10% for the DWI and 15 % for the Axb.

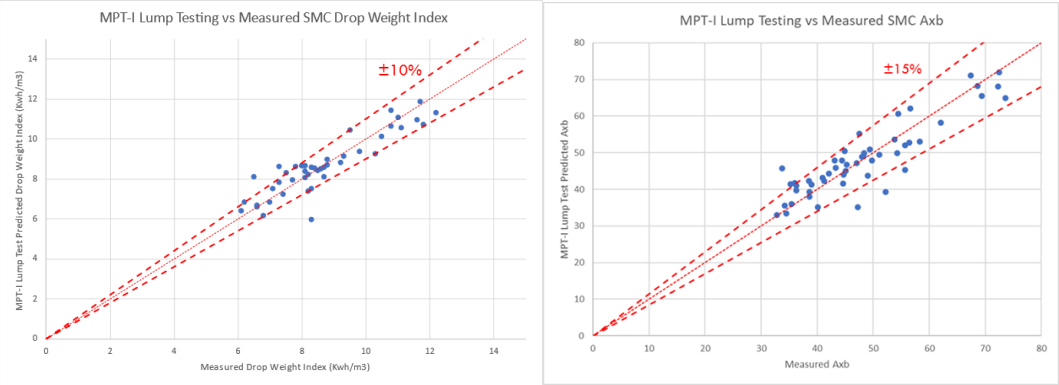


Figure 6 a) Comparison of MPT lump outputs and measured Drop Weight Index values (from SMC testing) b) Comparison of MPT lump outputs and measured Axb values (from SMC testing)

CONCLUSION

The development of the Minpraxis Tester, has the potential to revolutionize the field of geotechnical and geometallurgical characterization. Results show a significant improvement over traditional methods, offering a more integrated, efficient, accurate, and less time-consuming approach to traditional orebody characterization. Unlike conventional procedures that require multiple, separate analyses, the Minpraxis Tester consolidates these processes, allowing for a seamless integration with assay preparation workflows.

The potential for improving the size of a dataset is considerable, even with a conservative assumption that at least every half-core piece is characterized with the MPT. This is due to the technology offering two distinct advantages:

1. A finer interval of strength testing, which can increase the amount of data captured along a core run by approximately 50 times (compared to conventional methods).
2. The ability to characterize resource core that would otherwise not be tested with conventional approaches.

Taken together, these advantages can result in a significant increase in the size of the geo-metallurgical dataset, providing a valuable input for generation of geo-metallurgical block models that accurately represent the spatial variation within the orebody.

Currently, Bond ball mill work index predictions are predicted as proxy measurements that are deposit-specific. Further work is being done to extend the outputs to predicting Bond ball mill work indices by testing smaller size fractions, closer to 3.35 mm in size, using the MPT.

In summary, the MPT device generates both geotechnical and geometallurgical outputs that can be valuable for improving orebody knowledge. It provides the opportunity to substantially increase the information gained from available samples at different stages of project progression while in the case of MPT application at operating mines, there is a wide range of opportunities including implementation into an assay preparation laboratory for characterization of ore control samples and also for testing core samples that were drilled to assess expansion areas.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the valuable support provided by the mining companies who have collaborated through discussion and/or sample provision, entrepreneurship@UBC, InnovateBC, National Research Council of Canada, Canadian Trade Commissioner Service and MITACS.

NOMENCLATURE

MPT	Minpraxis Tester
UCS	Uniaxial Compressive Strength
PLT	Point load Test
DWI	Drop Weight Index

REFERENCES

ASTM D5731 (2017). - Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classification.

ASTM D2938 (2017). Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens.

Dussud, M., Kudar, G., Lounsbury, P., Pikul, P. and Rossi, F. 2019. Optimizing mining feasibility studies: The $100 billion opportunity. McKinsey & Company

Jackson, J. (2017). Leveraging the value of drilling for ore body knowledge. Australian Institute of Geoscientists Bulletin No.64 Drilling for Geology II: 26-28 July 2017, Brisbane, Australia

Lakshmanan, V. I., & Gorain, B. (2019). Ore Body Knowledge. In Innovations and Breakthroughs in the Gold and Silver Industries: Concepts, Applications and Future Trends (pp. 1–288). Springer International Publishing. https://doi.org/10.1007/978-3-030-32549-7

Morrell, S. (2004). Predicting the specific energy of autogenous and semi-autogenous mills from small diameter drill core samples. Minerals Engineering, 17(3), 447–451.

Nadolski, S., Pizarro, G., Hesse, M., Diaz, E., Henriquez, D. & Klein, B. (2023). Improving orebody knowledge with high-resolution rock strength characterization using the Minpraxis Tester. SAG2023 Conference proceedings.

Nadolski, S. (2019) Rock Hardness Measurement. US Provisional Patent. 62910780. United States Patent & Trademark Office

Nadolski, S. (2020) Rock Hardness Measurement. WIPO International Application. WO 2021/062556 A1. World Intellectual Property Organization

Şahin, M., Ulusay, R., & Karakul, H. (2020). Point Load Strength Index of Half-Cut Core Specimens and Correlation with Uniaxial Compressive Strength. Rock Mechanics and Rock Engineering, 53(8), 3745–3760. https://doi.org/10.1007/s00603-020-02137-9