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N. O. TIKHONOV *(JV "IVS")*
A. N. IVANOV *(RIVS Science and Production Association)*

ORE PRETREATMENT REENGINEERING AT OPERATING PROCESSING PLANTS USING HIGH PRESSURE GRINDING ROLLS—A PROMISING AREA OF ACTIVITY (IN TERMS OF ERDENET MINING CORPORATION)

N. O. TIKHONOV,
Head of Subdivision

A. N. IVANOV,
Director of Department

Ore pretreatment is the most money-taking stage of mineral processing at a plant. For this reason, enhancement of ore pretreatment processes is one of the allocated targets of the production improvement in mineral dressing industry.

Reengineering of ore pretreatment charts using high pressure grinding rolls (HPGR) as an additional stage of fine crushing of ore before feeding to milling cycle is a promising area of activity, which sometimes enables enhanced ore pretreatment efficiency at operating processing plants. Owing to reduced grain size of ore feed for milling, the milling equipment capacity grows by 15–20% depending on characteristics of an ore type and on the current ore pretreatment chart.

It is indispensably required to assess expediency of HPGR technology by means of laboratory and pilot-plant testing aimed at characterization of the behavior of ore in work zone of HPGR.

The current performance of the available crushing and grinding equipment and its test data provide source information for the JKSimMet simulation applied by RIVS to construction of mathematical model enabling high-reliable prediction of the production data obtained using an ore pretreatment chart depending on changes in the chart and in the equipment parameters.

The authors illustrate prospects of the described approach in terms of the technical-and-economic calculation project "Reengineering of ore pretreatment phase I, crushing stage IV" accomplished by RIVS for the processing plant of Erdenet Mining Corporation.

Improvement of ore pretreatment processes has always been a priority trend mining and processing modernization since ore preprocessing is the most expensive process stage of beneficiation.

One of the promising directions, which in some instances has enabled effectivization of ore pre-processing at operating plants, is redesign of an ore pre-processing circuit by introduction of high pressure grinding rolls as an auxiliary stage of fine crushing of ore before grinding. Reduction of size of the ore grinding feed allows the increase in the milling equipment output by 15–20% depending on features of a specific ore type and on characteristics of the current ore pre-processing chart.

In order to estimate material behavior in the work zone of HPGR, laboratory and semi-commercial tests are carried out as a compulsory stage of feasibility study of the technology application under certain conditions.

At the present time, RIVS is designing new charts and upgrades the existing schemes of ore pre-processing based on the test data and current process indexes of crushing and grinding equipment on hand using JKSim computer simulation software package. The obtained mathematical model allows high-reliable forecasting of the production data of the ore pre-processing chart at varied parameters of the involved equipment.

As an illustration of the described approach, the article presents the technical-and-economic calculation for "Ore Pre-Processing Stage I Technical Upgrading, Crushing Stage IV" accomplished for the processing plant of Erdenet Mining Corporation.

Key words: *ore pretreatment, high pressure grinding rolls, testing, modeling, design.*

Many operating processing plants face challenges that were absent at the early stages of their activity. Processing involves ore minerals extracted from new deposits or ore taken at deeper levels in the existing mines. In this case, not only content of useful components but also physico-properties (hardness, abrasiveness) of ore can change. These factors, as a rule, add value of the final marketable concentrate. Under the circumstance, many operating processing plants search for ways of increasing the production output.

One of the promising directions toward this problem handling is modernization of ore pretreatment charts using high pressure grinding rolls (HPGR) as an additional stage of fine crushing of before milling. Reduction of crushed ore size enhances output of milling equipment by 15–20% (sometimes even higher) depending on characteristics of ore and on the current ore pretreatment chart [1].

Since first introduction of HPGR in cement production in 1986 for clinker grinding, designers have made progress in update of the mill structure and selection of materials required to make rolls, which has resulted in the increased efficiency of HPGR up to 94%; furthermore, maintainability and serviceability of the mills has grown [2, 3].

Modern HPGR have very small dimension and, this, need smaller understructure as against conventional cone crushers. HPGR have low vibration and noise level, and ore dust in the course of breakage is readily removed by aspiration systems.

At present HPGR are produced by many machine-building companies. The key position belongs to Polysius (ThyssenKrupp Resource Technologies GmbH), KHD (KHD Humboldt Wedag AG) and Köppern (Maschinenfabrik Köppern GmbH & Co KG), which are Germany companies. All manufacturers adhere to the same layout diagram of the mill as shown in **Fig. 1**, with different designs of individual units.

Fig. 1. HPGR: general view and structural components

The structure of HPGR includes:

- 2 roll units, each having two bearing assemblies, steel roll, lining shell;
- 2 drive systems, each having electric drive, voltage-dropping reducing gear;
- Drive shaft;
- Hydropneumatic pressurization system;
- Feeding device, including charging box, internal guide plates, other components;
- Body frame;
- Lubricating system.

The prime objective of planning ore pretreatment with HPGR is the selection of the machine dimension to ensure the desired capacity of the preset reduction in crushed ore size. Capacity of HPGR is mainly governed by the geometry of rolls, type of lining shells and physico-mechanical properties of ore mineral to be ground. For the chosen dimension HPGR, its capacity is adjusted by means of the roll speed.

The grain-size composition of the mill product is controlled by grinding force between rolls, owing to which the mill product undergoes high pressure in the compression zone, which, in its turn, results in micro-fracturing and breakage of minerals. At the present time, the grinding force and grain-size composition are correlated experimentally for each material type in the course of testing.

After preliminary laboratory research and semi-commercial trials, the next indispensable stage is estimation of HPGR expediency in the particular application conditions. The estimation involves:

- General consistency of the test ore and high pressure grinding method;
- Key process parameters of HPGR (unit capacity, unit compression force and unit energy input);
- Grain-size composition of ground material;
- Abrasing effect of ore on lining shell walls.

The analysis record includes some parameters, for instance, the true and bulk specific gravity of ore, pre-breakage grain-size composition, moisture content, bulk gravity of ore after compression in work zone of rolls, speed of rolls, total grinding force, wattage used, pressure of pressurization system, spacing of rolls before feeding the mill, spacing of rolls in work; specific energy consumption, capacity, grain-size composition of ground product (sampled in the middle and edge zones, and of total discharge), ratio of products from the middle and edge zones.

Based on the test data and the current production data of the available crushing and grinding equipment, using JKSimMet simulation computer software package applied by RIVS to development and modernization of ore pretreatment charts, the mathematical model has been constructed for highly reliable forecasting of production data of an ore pretreatment chart depending on the change in the milling and equipment parameters.

By way of illustration, the data of the process design implemented by RIVS within the framework of the project on “Reengineering of ore pretreatment phase I, crushing stage IV” at the processing plant of Erdenet Mining Corporation. The process design was aimed at development of an ore pretreatment technology to increase ore crushing and transportation capacity from actual 20.6 Mt/yr up to 25 Mt/yr without additional milling equipment.

With the intent to prove applicability of HPGR in the cooperating conditions of Erdenet Mining Corporation, refinement of estimated production data and selection of the mill work mode, the process of ore breakage by high pressure rolls was tested on a pilot stand of the Thyssen Krupp laboratory for the purpose of determining:

- Grinding force required;
- Effect of moisture content of the feed on the properties of the ground material, and on the output and wear of the mill;
- Specific capacity;
- Circulating load;
- Adjustment of Bond Ball Mill Index of HPGM product.

Based on the test results and subsequent calculation data, it is concluded that HPGR will allow reduction of ground ore size with the simultaneous increase of 2.5 mm size grade in the ground ore content up to 50–55%. That will enable higher capacity of the same milling equipment and the required size of the ground product for further dressing stages.

Erdenet Mining Corporation uses the classical three-stage crushing chart with the closed cycle at stage III (fine crushing) for ore pretreatment. The flow chart (including milling stage I) is shown in **Fig. 2**.

Dump trucks bring ore –1000 mm in size from open pit mine to two crushers KKD-1200/130GRSHCH. In front of the crushers, there are bar screens with a slot width of 150 mm. Oversize product goes to the crushers, and undersize is mixed with the crushed ore –250 mm in size and fed to hoppers, wherefrom feeders and belt conveyors carry it to a coarse-crushing ore storehouse.

Crushing stage II (open cycle with screens GPKT-72U) uses crushers KSD-2200T2-D (5 crushers). The crushed product is transported to an intermediate storage facility in the mid- and fine-crushing area. Then, the ore is milled by fine crushers KMD-3000T2-DP (6 crushers). The oversize product of screens GPKT-72U installed ahead of the crushers is returned to the mid-crushed ore storage facility, which forms the closed cycle of fine crushing.

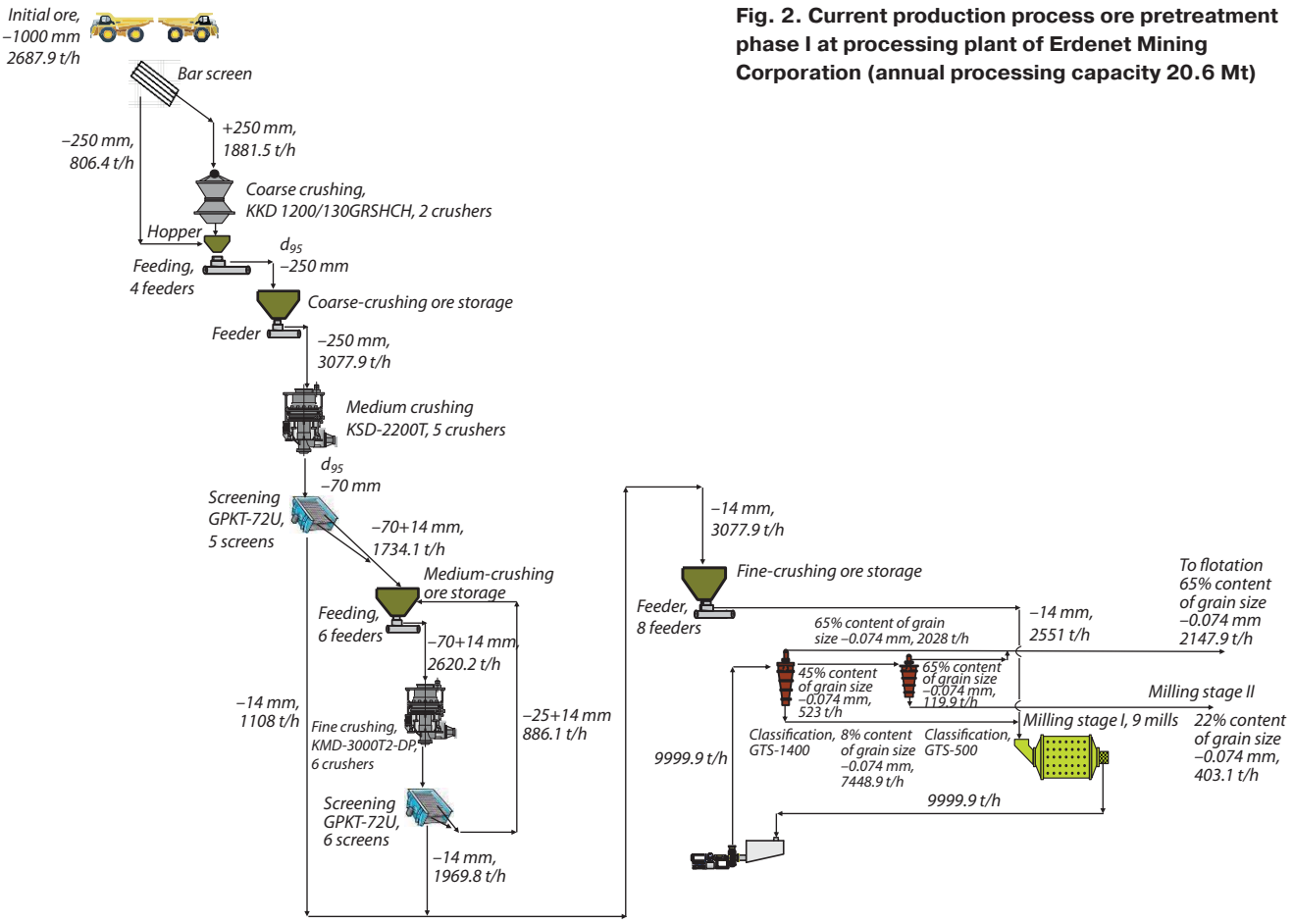

Fig. 2. Current production process ore pretreatment phase I at processing plant of Erdenet Mining Corporation (annual processing capacity 20.6 Mt)

The undersize product of all medium and fine crushing screens (rated size d_{95} = 14.8 mm) is conveyed to a fine-crushing ore storehouse, wherefrom it is fed to milling stage I (6 mills MSHCHTS-5500×6500 and 3 mills MSHTS-5800×6900); the mills operate in a closed cycle with three-product cyclone GTS-1400. Fine discharge of the cyclones, with 65% content of –0.074 mm size grade, flows by gravity to a conditioning tank for treatment prior to bulk flotation.

Efficiency of the entire process is governed by the performance of the closed cycle of the fine crushing stage. The available crushers, given the current size grade of the feed, are incapable of increasing the processing capacity more than by 5–7% with keeping the required size of the ground ore.

It is worthy of mentioning that Erdenet company has done its best in upgrading and reequipment of ore pretreatment, which enabled enhancement of processing capacity from the design value of 16 Mt/yr up to the actual level of 20.6 Mt/yr. The goal was achieved owing to replacement of fine crushers KMD-2200 for crushers KMD-3000T2-DP, inclusion of additional crusher KMD-3000T2-DP in the medium- and fine-crushing circuit, and replacement of the available screens for the more efficient models. That resulted in the reduction of the ground product size from 25 to 14.8 mm, which ensured enhanced capacity of the process with the available milling equipment.

However, all reserves are now depleted and further increase in the processing capacity is impossible without a drastic change of the ore pretreatment technology. At the same time, RIVS and Erdenet have carried out full-scale reequipment of flotation area, which offers an opportunity of expanding essentially the processing capacity.

In accord with the developed engineering designs, it is suggested to operate fine crushers in open cycle mode, which will eliminate cycling loading of the crushers and enable higher processing capacity without additional crushers at fine crushing stage III, while the fine crushing product will be sent to milling by HPGR operating in a semi-open cycle with recirculation of middlings having the highest content of larger-size fractions. The flow chart with the use of HPGR (including milling stage I) is shown in **Fig. 3**.

In conformity with the engineering decisions, the milling feed size (d_{95} — grain size by 5% screenings; $d_{w.a}$ — weighted average grain size; F_{80} — grain size by 20% screenings) will change as follows:

- currently (after crushing by KMD): d_{95} = 14.8 mm, $d_{w.a}$ = 7.5 mm, F_{80} = 12.2 mm;
- project (after milling by HPGR): d_{95} = 10.8 mm, $d_{w.a}$ = = 2.9 mm, F_{80} = 7.1 mm.

Furthermore, as follows from the test results, HPGR allow reduction in the Bond Index by 10% due to weakening of ore under high pressure [1]. Owing to this, the enhancement

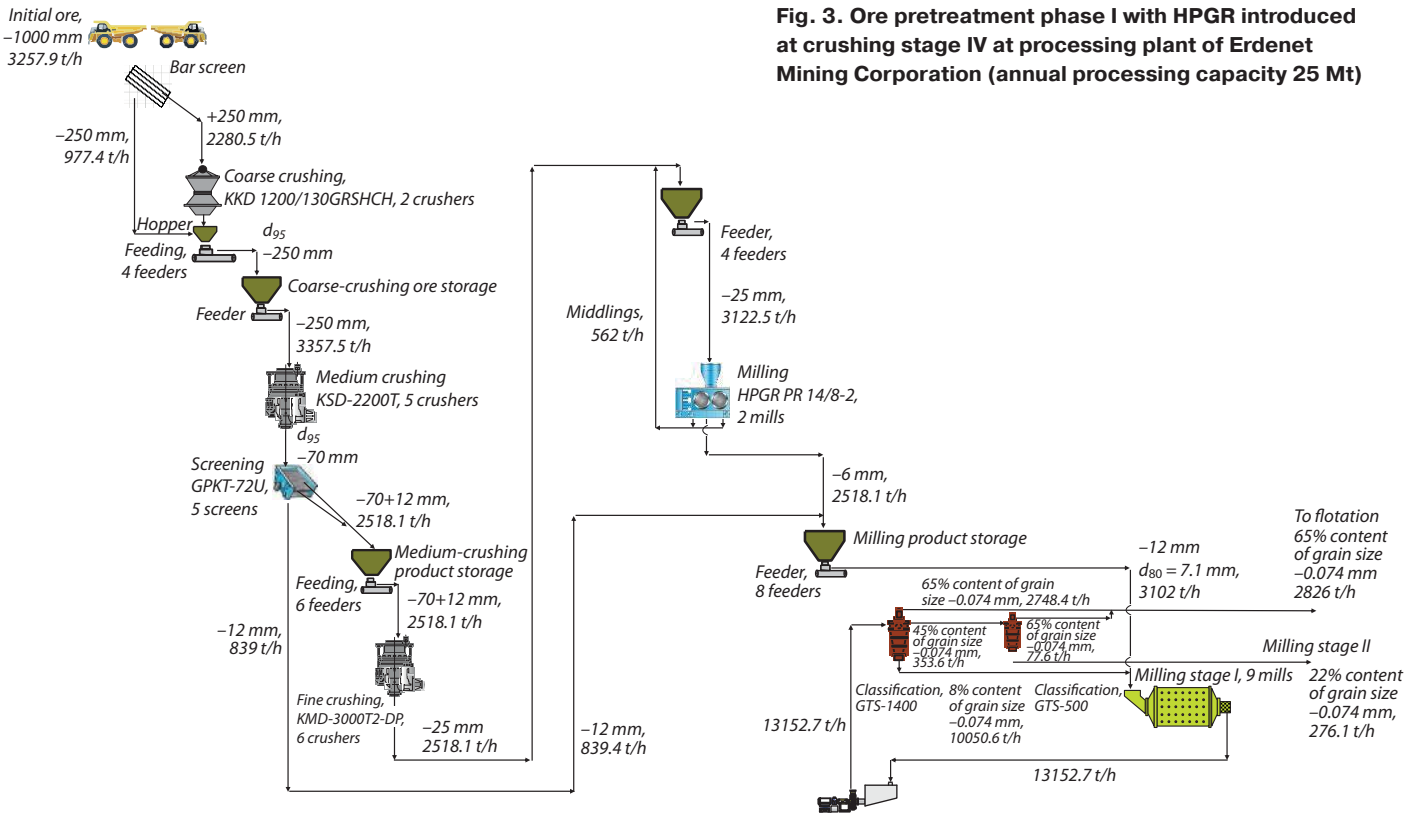

Fig. 3. Ore pretreatment phase I with HPGR introduced at crushing stage IV at processing plant of Erdenet Mining Corporation (annual processing capacity 25 Mt)

of the ore processing capacity by 20% and maintenance of the designed capacity of 25 Mt/yr is achievable with the available milling equipment.

The scope of work performed by RIVS included also design solutions on arrangement and structure of milling equipment.

According to the economical estimate, the payback time of the new equipment will take 2 years and 9 months starting from the commissioning period.

Mills HPGR are surely not a broad-based solution. In each particular case, it is required to analyze the current conditions and characteristics of a particular ore material, to carry out trial test and, then, computer-aided modeling of the performance prediction ended with a detailed economical design.

However, it is indubitable that HPGR creates favorable conditions for next following production processes. Potential saving of energy for further grinding (and the entire ore pretreatment cycle) results in appreciable cut-down of capital and operating costs. The introduction of HPGR makes feasible processing of low-grade ore, which is impossible with the conventional technologies of crushing and semiautogenous milling.

RIVS Science and Production Association maintains working partnership with leading HPGR manufacturers, is in possession of ample experience in ore pretreatment design and modernization, and holds advanced computer-aided engineering tools (program JKSimMet and proprietary software). Design office RIVS-Proekt, being the part of RIVS, practices innovative design solutions, thus, allowing RIVS to accomplish the required scope of work connected with fruitful commissioning of HPGR, starting from arrangement and execution of the required research and economical analysis of the new machinery expediency and closing up with engineering documentation delivery and technical support of the project actualization on site.

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Tikhonov Nikolai Olegovich,
Ivanov Alexander Nikolaevich,
e-mail: rivs@rivs.ru