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MODELLING AND SIMULATION OF GRINDING CIRCUIT IN MADNEULI COPPER CONCENTRATOR

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In this study, modelling and simulation studies to improve the performance of grinding circuit of Madneuli Copper Flotation Plant in Georgia were presented. After detailed sampling surveys, size distribution and solids content of the samples were determined. Then, mass balance of the circuit was calculated using these data. The results showed that the existing performance of the plant was not good and required to be improved. Using the data obtained, the models were developed for the mills and classifiers used in the circuits. Finally, several alternatives for a better performance were evaluated by using computer simulation. The results showed that the performance of the circuit could be improved and energy consumption in the grinding circuit could also be decreased.

Key words: grinding, modelling, simulation, classification

INTRODUCTION

Madneuli concentrator has a design capacity of 1610000 tons per annum consists of three parallel grinding circuits. While two of them are identical and have an annual capacity of 680000 ton., third circuit has annual capacity of 250000 tons.

A performance evaluation study in a flotation plant indicated that the flotation feed fineness should be incresed to improve the flotation performance (Ergün et al, 2000).

Simulation of the grinding circuits using mathematical models of the mills and classifiers is a technique which is being used increasingly in comminution because of its low cost and its ability to consider many variables simultaneously (Lynch 1977, Napier-Munn et al., 1996).

Simulation would provide the quantified information about the effects of the proposed changes on the circuit performance in terms of size distribution, solid and water flowrates etc. Such information could then be used to check the suitability of the existing equipment to the modified conditions, and for equipment selection.

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The aim of the study was to develop mathematical models of ball mills and classifiers used in the grinding circuit and to investigate the effects of the proposed modifications on the circuit performance using simulation. For this purpose, sampling surveys were carried out around the circuit. The size distributions of the samples formed the main data basis for the following simulation studies. The raw data was first mass balanced. Then, they were used for the calibration of the equipment models for the circuit. Finally, the effects of a number of flowsheet changes as well as the effects of changing operating parameters on the circuit performance were investigated by computer simulations using calibrated models.

SAMPLING AND LABORATORY STUDIES

To evaluate the performance of grinding circuits and to obtain the data required for the modelling studies, samples were taken from the points marked in Figure 1. Because of the similarity of the three different circuits, sampling and performance evaluation was only applied to the second circuit in the plant.

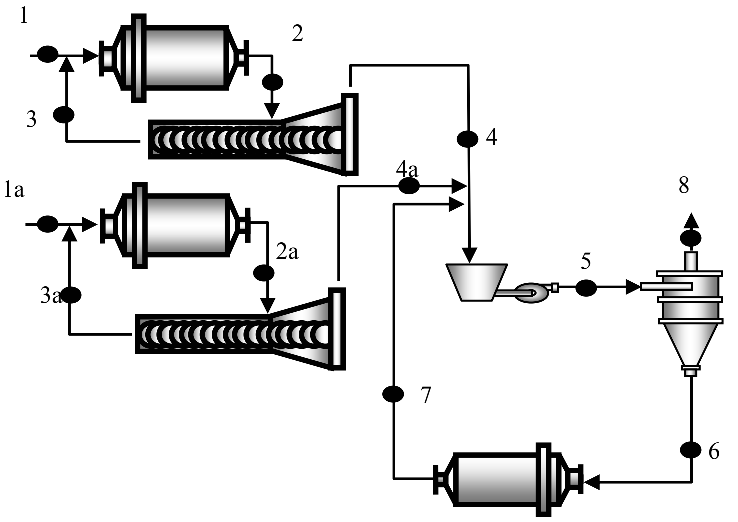


Fig. 1. The simplified flowsheet and sampling points around the circuit

For this purpose, pulp samples were taken from grinding circuits. All samples were dried, weighed and sieved. Size distribution of each sample was determined down to 6 µm. Mass balancing of grinding circuits were performed to calculate the flowrates in each stream.

All the size distributions of the samples taken were determined. In order to characterize the breakage characteristics of the ores at the mine Work index and drop weight breakage function were measured.

Work indices of the samples were determined by using standard Bond Work index test. The results are given in Table 1.

Table 1. Bond work indices of the different ore types in Madneuli deposit.

	Plant feed	Oxidised ore	Sulphide ore	Complex ore
Wi (kWh/ton)	10.1	6.27	12.53	13.84

Despite the major variations among the work indices of the different ore types, the plant feed prepared by blending the three ores gives a mean value. Breakage functions of the ore were also measured to expose the breakage behaviour of the ores. These data give us the opportunity to reflect different breakage characteristics to the model structure. Breakage functions of the three different ores are illustrated in Figure 2.

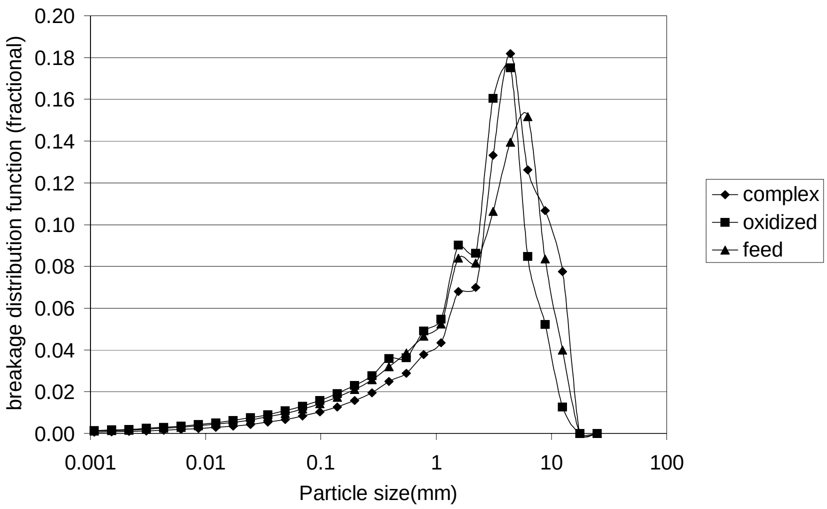


Fig. 2. Breakage functions of different ores mined in Madneuli ore deposit

MASS BALANCING

To evaluate the existing performance of the grinding circuit mass balancing studies were carried out by using the plant survey data. The flow rates are given in Figure 3. During the sampling survey the plant capacity was measured as 84.5 tph. The measured value of the flotation feed fineness was found to be only about 43-45% -74µm in the circuit. After mass balancing, to compare the measured and calculated values, the size distributions of the measured and calculated data were plotted. The following figures show this comparison for each point in the circuit (Figure 4-5).

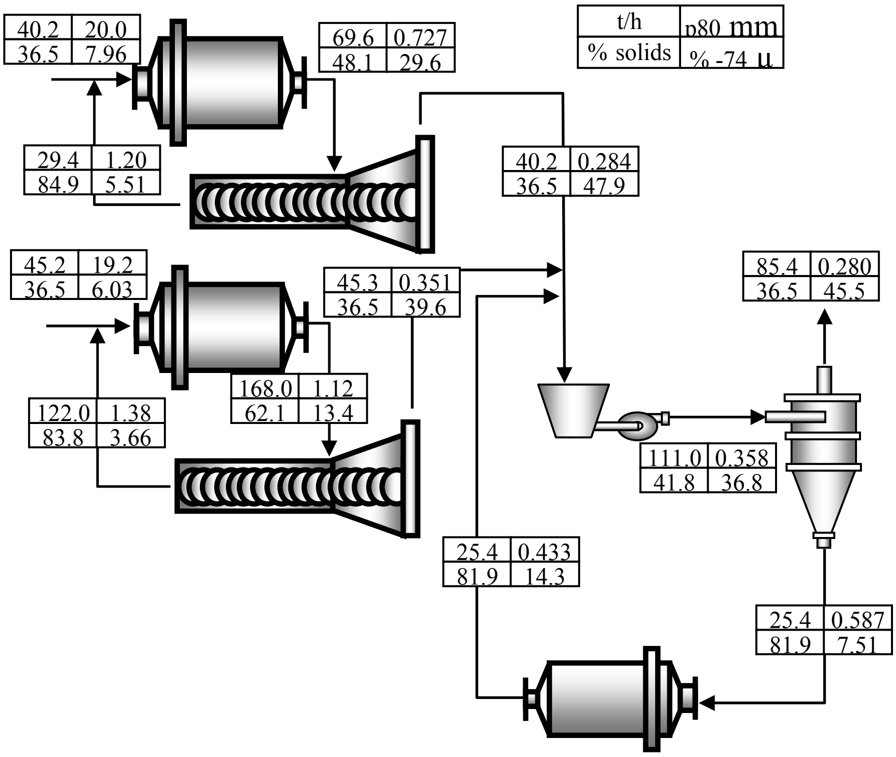


Fig. 3. Flow rates after mass balancing

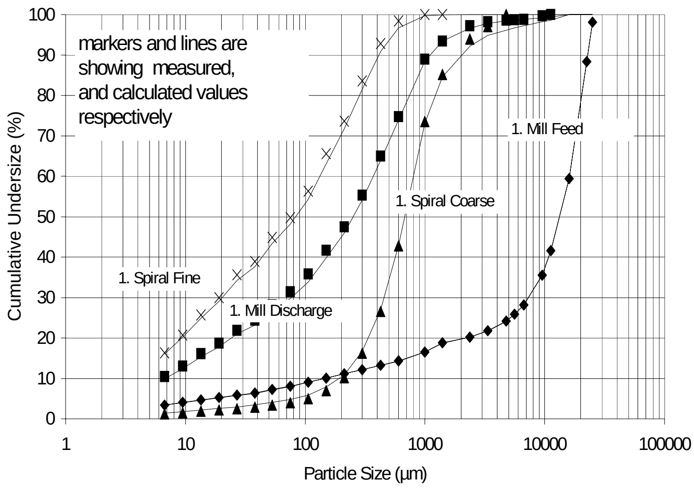
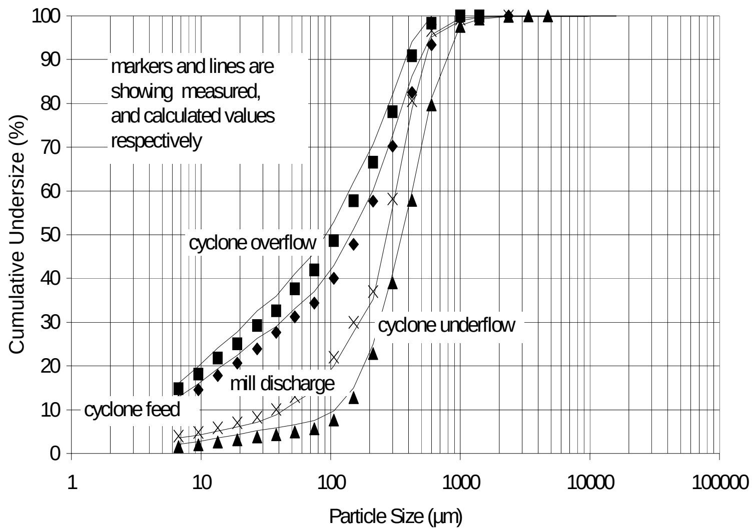
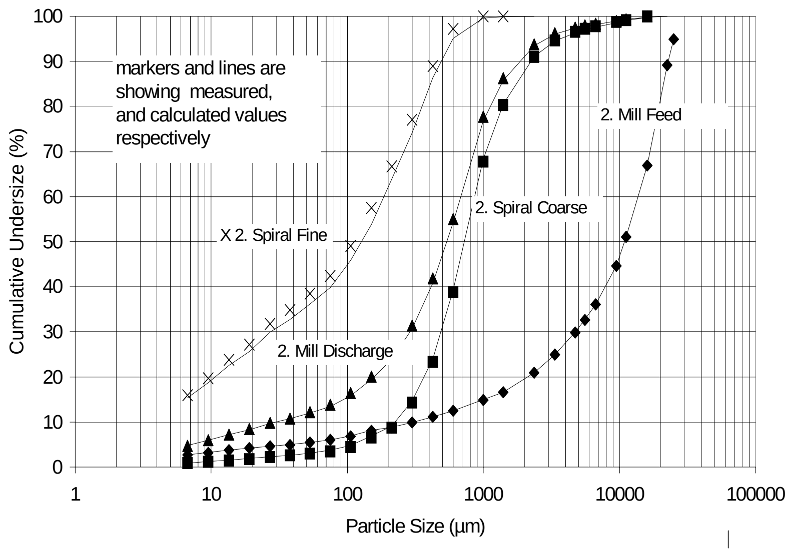


Fig. 4. Measured and mass balanced values around 1st, 2nd primary grinding circuit



(a)



(b)

Fig. 5 a, b. Measured and mass balanced values around secondary grinding circuit

MODELLING STUDIES

As shown in the figures, mass balance of each stream was obtained without any significant correction on the measured data. Therefore, the data obtained from mass balance could be used for modelling of the grinding circuit. Then, models for each unit in the circuit were developed by using mass balanced data.

The models used are the perfect mixing model for ball mills and the efficiency curve model for separators.

Ball mill model for steady state operations includes two sets of model parameters, i. e. the breakage function (a_{ij}) and a combined breakage/discharge rate (r_i/d_i) function.

$$f_i - r_i \frac{p_i}{d_i} + \sum_{j=1}^{i} a_{ij} . r_i . \frac{p_i}{d_i} - p_i = 0 \tag{1}$$

Calibration of a ball mill model is the calculation of r / d values using the feed and product size distributions obtained under particular operating conditions.

Classifiers are modelled using efficiency curve approach (Napier-Munn *et al*, 1996). The mathematical model selected for the study is capable of defining the fish hook type efficiency curves. The general form of the equation is presented below.

$$\mathrm{E}_{oa} = C \left[\frac{(1+\beta \cdot \beta^{*} \cdot X)(\exp(\alpha)-1)}{\exp(\alpha \cdot \beta^{*} \cdot X) + \exp(\alpha) - 2)} \right] \tag{2}$$

where

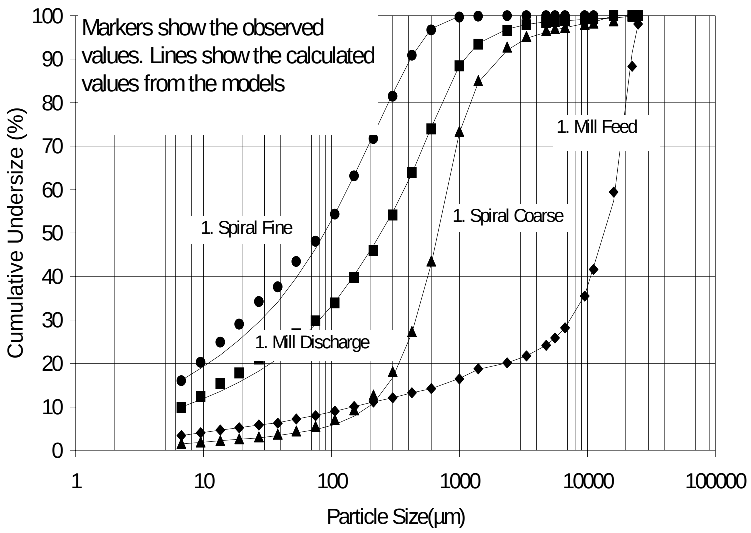
$$X = \frac{d_i}{d50_c} \tag{3}$$

In cases where the efficiency curve does not exhibit fish hook behaviour, the parameter β is equal to zero and a simplified form of this equation is obtained:

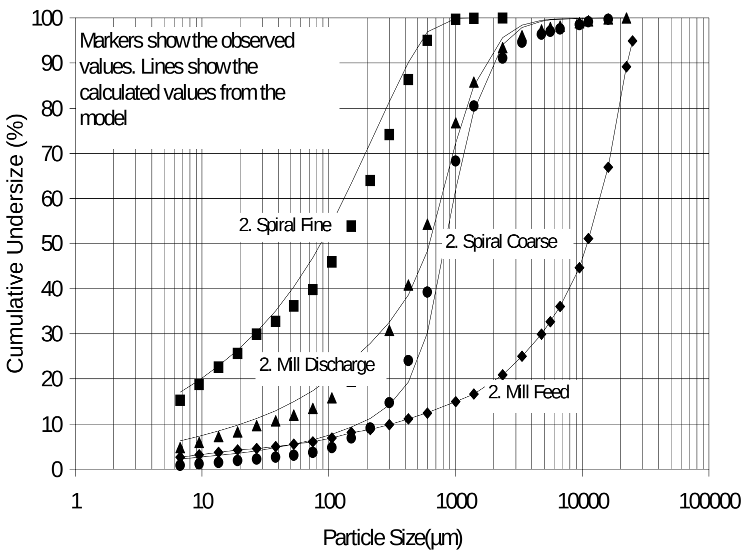
$$\mathrm{E}_{oa} = C \left[\frac{\exp(\alpha) - 1}{\exp(\alpha \cdot X) + \exp(\alpha) - 2} \right] \tag{4}$$

The classifier performance can be modelled in terms of d50(corr), by-pass (1-C), the "fish hook"(β), and the sharpness of the curve(α) .

In order to control the accuracy of the models, size distributions of each stream were calculated by using only the size distribution of the feed. The following figures show the comparison of measured and predicted size distributions (Figures 6-7).



(a)



(b)

Fig. 6 a, b. Measured and predicted values around 1st and 2ndprimary grinding circuit

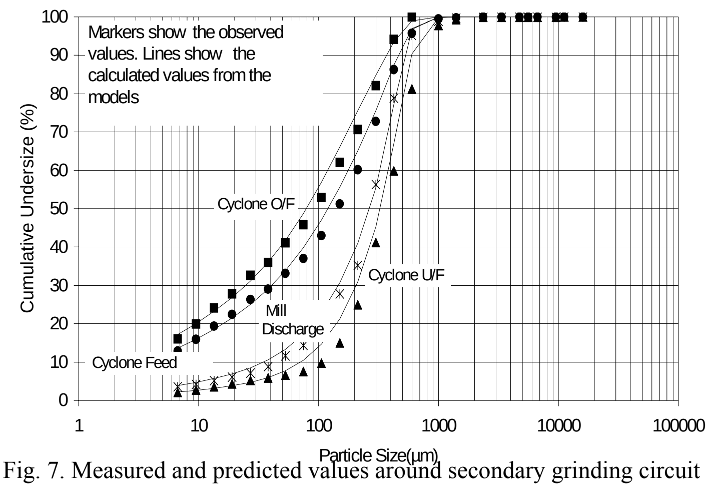


Fig. 7. Measured and predicted values around secondary grinding circuit

The figures show clearly that the plant conditions can be simulated perfectly by the models derived. Thus, several operation alternatives were tested during simulation studies to obtain optimum conditions.

SIMULATION STUDIES

Mass balance studies indicated that the circuit was operating under its design capacity which is 100 tph. Therefore, during simulation studies first the performance of 100 tph and 110 tph were predicted. As expected, the flotation feed became coarser. These figures provided a basis for further simulation studies. Then, simulation studies were performed by modifying ball size, cyclone geometry, feed size and % solids in the primary ball mill to obtain optimum conditions for the existing and alternative flowsheets. Simulation results are summarised in Table 2.

Table 2. The results of the simulation studies

	Feed rate (t/h)	1st & 2nd primary grinding circulating loads (t/h)	Secondary grinding circulating load (t/h)	Final product fineness % -74 µ
Existing conditions	100	42.5 & 145	31.0	42.9
Existing conditions	110	49.9 & 170	35.1	42.2
Optimum conditions	100	34.8 & 35.7	17.2	62.0
Optimum conditions	110	74.1 & 74.4	19.7	60.6
Hard ore (Wi:13.84)	100	41.0 & 42.2	19.2	58.3
Cyclone diameter:500 mm	100	34.8 & 35.7	80.6	69.3
Cyclone diameter:650mm	100	34.8 & 35.7	82.8	68.7
Cyclone diameter:700 mm	100	34.8 & 35.7	85.2	67.4
Cyclone diameter:750 mm	100	34.8 & 35.7	81.5	67.7

During the simulation studies, an alternative grinding circuit was also proposed. In this alternative, primary ball mills was replaced by a rod mill of which model parameters are known. The rod mill parameters were taken from another study (Ergün et al., 2000). Instead of using the three ball mills each having a motor power of 630 kW in the circuit, a rod mill with 400 kW motor power and a ball mill operating in series would provide the same fineness at higher capacities with the power savings of 45 %. The flowsheet of the existing and this alternative grinding circuit is given in Figure 8.

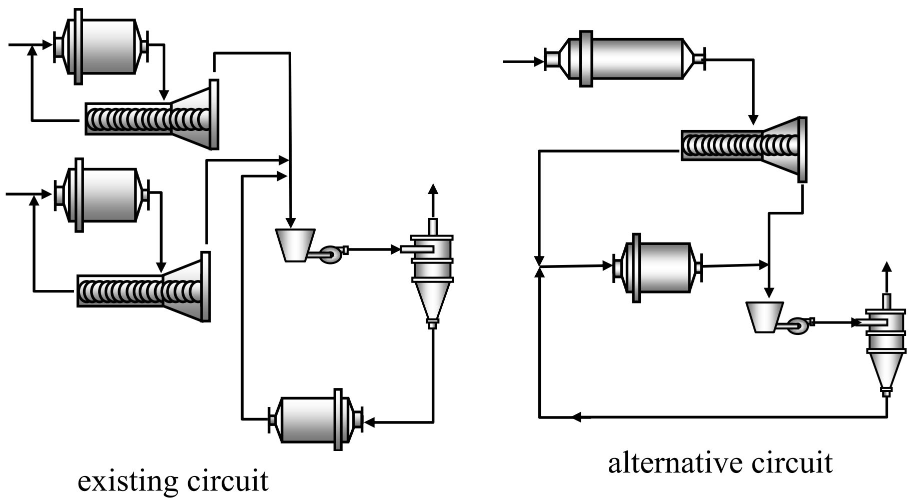


Fig. 8. The flowsheet of the alternative circuit in which rod mill is used

On this alternative circuit, the effects of various operation conditions on circuit performance were also predicted. The results of these simulation studies are summarised in Table 3.

Table 3. The results of these simulation studies

	Feed rate (t/h)	Ball mill circulating load (t/h)	Final product fineness % -74 μ
Optimum conditions	100	154	64.0
Optimum conditions	110	174	62.9
Cyclone diameter:500 mm	100	102	66.1
Cyclone diameter:650mm	100	106	65.5
Cyclone diameter:700 mm	100	109	64.0
Cyclone diameter:750 mm	100	105	64.4
Hard ore (Wi:13.84)	100	142	59.9

CONCLUSIONS

In this study, the performance of the existing grinding circuit in Madneuli copper plant was determined. The results showed that the existing performance of the grinding circuit could be improved and the fineness of the flotation feed could be increased to the desired value.

Two alternatives were proposed. First, optimisation of the existing circuit to produce finer product and second using combination of rod and ball mill instead of the existing two stage ball mill grinding. These alternatives will provide finer product with higher capacity and flexibility to increase the capacity. Besides production of finer product, rod and ball mill combination will reduce the energy consumption significantly.

Bond tests indicated that the different ore types in the plant have got different work indices. Therefore, it can be concluded that blending of the plant would provide a consistent feeding to the plant. The breakage tests showed that the material have got a brittle structure and can easily be broken under impact mechanism.

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Ergün L., Ekmekçi Z., Gülsoy Ö., Benzer H., *Modelowanie i symulacja węzła mielenia w zakładach wzbogacania miedzi Madneuli,* Physicochemical Problems of Mineral Processing, 38, (2004) 231-240 (w jęz. ang.).

W pracy zostały przedstawione modelowe badania symulacyjne mające na celu poprawę parametrów ruchowych sekcji mielenia w zakładzie wzbogacania rud miedzi Madneuli w Gruzji. Instalacja mielenia i klasyfikacji została opróbowana. Skład ziarnowy i zawartość części stałych w pobranych próbach zostały określone. Na podstawie zebranych danych został wykonany bilans masowy instalacji. Otrzymane z bilansu wyniki wskazują, że działający węzeł mielenia i klasyfikacji nie działa prawidłowo i wymaga poprawy. Został zoptymalizowany układ mielenia i klasyfikacji. Kilka alternatywnych rozwiązań wynikających z symulacji komputerowej zostało zaproponowanych. Otrzymane wyniki wskazują, że praca węzła mielenia i klasyfikacji może zostać poprawiona a zużycie energii w procesie mielenia także obniżone.