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ABSTRACT 507

New project in Russia with semiautogenous mill selected according to the results of SAGDesign testing

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ABSTRACT

The paper contains description of a new project in Russia – gold-processing plant at Aleksandrovskoye deposit (start up in September, 2013). The paper includes a brief description of plant flowsheet, data for material composition and technological properties of ore, as well as information about the achieved parameters of ore processing over the first months of plant operation.

The project is interesting because a new semiautogenous mill and a ball mill were purchased on the basis of SAGDesign Consulting Group recommendations after the testing of ore samples characterizing the deposit according to specific years of operation.

The plant has relatively small design capacity – 750 000 tpa, but nevertheless is the biggest gold-processing plant in the territory of Zabaikalsky region. Major valuable component in the ore is gold, silver is recovered as a by-product. The ores are highly refractory to grinding.

The design grinding flowsheet includes a semiautogenous mill operating in a locked cycle with a screen, and a ball mill operating in a locked cycle with hydrocyclones (SAB). Process technology includes gravity processing and flotation with subsequent cyanide leaching of concentrates.

Mill operation analysis and conclusions about the compliance of the achieved values to target ones are shown, as well as the accuracy of SAGDesign method when applied to very hard ores of Aleksandrovkoye deposit are presented in this paper. Basic directions of technological flowsheet optimization are also given.

INTRODUCTION

"Rudnik Aleksandrovsky"plant is the first plant in Russia constructed on a "turn-key" basis where comminution flowsheet was developed using the results of SAGDesign testing. Aleksandrovsky deposit is characterized by extremely hard ores refractory to grinding process.

TOMS institute carried out project support of design and engineering works from the moment of sample testing in 2010 till the plant start-up in September, 2013. After the plant commissioning TOMS specialists have been taking part in technological processes and equipment adjustment aiming at design parameters achievement.

The first months of plant operation confirm the correct decisions made at the stage of technology development and equipment selection. At the moment of this paper preparation, the plant provided the design capacity in spite of the difficulties connected with the ore supply because of the winter season. There were some issues with getting the required grind size of ore, but the technological team with TOMS specialists was working on solving these issues.

The method of testing and analysis of SAGDesign Consulting Group confirmed its applicability to extremely refractory ores from Aleksandrovskoye deposit. Therefore this method is recommended to be applied to similar projects with very hard ores.

DESCRIPTION OF DEPOSIT AND PROCESS TECHNOLOGY

Aleksandrovskoye deposit is developed by "Rudnik Aleksandrovsky" CJSC. This deposit is located in the South-East of Russia, in Mogocha region of Zabaikalsky territory, close to Davenda settlement (see Figure 1). The plant was officially opened on September, 24, 2013.

Figure 1 Location of Aleksandrovskoye gold-processing plant (information from: <https://maps.google.com/>)

The ores from Aleksandrovskoye deposit are of gold-quartz low-grade sulfide type. Ore minerals (1%) are represented by pyrite, chalcopyrite and galena. The only valuable component in the ore is gold, which is observed in its native form up to 1.4 mm in size, with grade ranging from 1.3 to 2.9 g/t. Silver is recovered concurrently.

The ore is mined from an open-pit of Aleksandrovskoye deposit. The mined ore is processed at the gold plant with design capacity of 750 000 tpa, the plant is constructed based on TOMS institute design (2010-2012).

The general overview and plant infrastructure is shown in Figure 2.

Figure 2 Mining and processing plant general overview and infrastructure

DESIGN CRITERIA

Basic design criteria of gold plant at Aleksandrovskoye deposit are shown in Table 1.

Table 1 Plant design criteria

Parameter	Value
Plant operation	Annual
Amount of working days per year	365
Plant operation mode, h/day	24
Equipment availability factor, %	94
Head material production, tph, tpa	91 / 750 000
Head ore maximum size, mm	700
Ore specific gravity, t/m^3	2,7
Gold recovery to ingots, %	92

The process flowsheet includes the following operations:

1. Ore preliminary crushing in a jaw crusher.
2. Ore homogenization at a storage.
3. Crushed ore grinding in a SAG mill in a closed cycle with a screen.
4. SAG mill product grinding in a ball mill in a closed cycle with hydrocyclones.

5. Gravity processing in a centrifugal concentrator with batch discharge of concentrate in grinding circuit.
6. Thickening of tailings from gravity processing.
7. Additional gravity processing of flotation feed in a centrifugal concentrator with batch discharge of concentrate.
8. Flotation of gravity tailings (rougher, scavenger and two cleaner operations).
9. Regrinding of gravity concentrate from additional operation blended with intensive cyanide leaching cake and flotation concentrate in a ball mill in a closed cycle with hydrocyclones.
10. Thickening of reground flotation concentrate (blend of concentrates and intensive cyanide leaching cake).
11. Cyanide leaching of individual concentrates, including:
   11.1. Intensive cyanide leaching of gravity concentrate.
   11.2. Sorption leaching of flotation concentrate.
12. Detoxification of cyanide leaching tailings.
13. Cathode deposit smelting and gold alloy receiving.

Process flowsheet is represented in Figure 3.

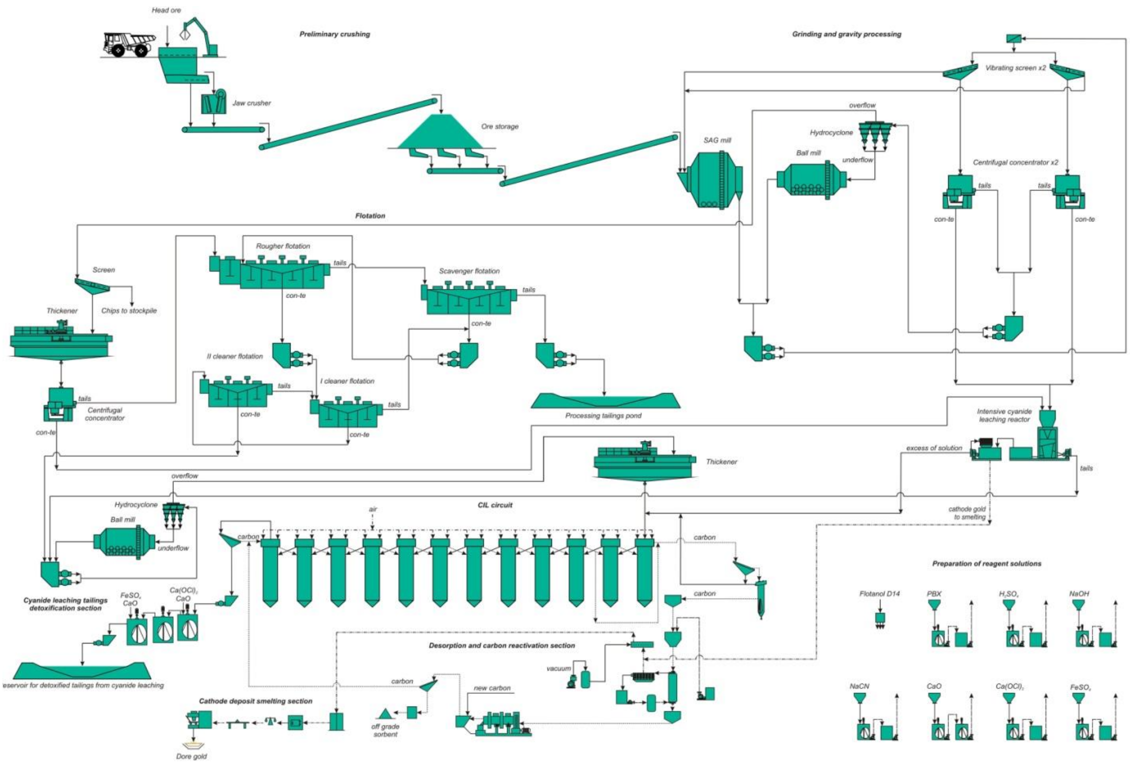

Figure 3 Process flowsheet

The characteristic feature of this process flowsheet is the way of feeding the ground product from SAG mill to screening. Unlike conventional arrangement when the screen is installed at the mill discharge, here the ground material is pumped. The screens are installed so that oversize material goes to SAG mill feed under gravity. This kind of circuit arrangement helped to remove belt conveyors for screen oversize product return. The screen simultaneously performs two tasks – control of SAG mill final grind size (transfer product – T80) and final screening before centrifugal separation.

SAGDESIGN TESTING

Selection of grinding equipment was completed based on the results of testing according to SAGDesign Consulting Group method in TOMS institute laboratory (2010).

The samples under investigations are characteristic of the following sites of the deposit:

- Sample No.1 – is represented by the hardest ore from the deposit;
- Sample No.2 – is represented by the composite sample of the first year of plant operation and consists of microdiorites;
- Sample No.3 – is represented by the composite sample from the second to the fifth year of plant operation and consists of 70% granites and 30% diorites;
- Sample No.4 – is represented by the composite sample which corresponds to gangue and consists of 50% granites and 50% diorites;
- Sample No.5 – is represented by the composite sample of the ore after 5 years of deposit development and consists of 80% diorites and 20% granites.

Table 2 contains summary results of SAGDesign testing of the samples from Aleksandrovskoye deposit.

Table 2 Summary results of SAGDesign testing of the ore from Aleksandrovskoye deposit (2010)

Parameter	Parameter value / Ore sample				
	1	2	3	4	5
Starkey index, W_{SAG}, KWh/t	18.14	12.22	13.64	12.78	11.94
Bond index, BWi, KWh/t	23.04	18.90	19.15	18.68	20.06
W_{SAG} + BWi, KWh/t	41.18	31.12	32.79	31.46	32.00

Figures 4-6 plot the results of physical and mechanical properties study of the ore from Aleksandrovskoye deposit compared to TOMS institute database of the earlier studied ores. The following conclusions are made from these graphs.

AG/SAG index for the studied ores varied within the wide range from 11.94 to 18.14 KWh/t. The highest ore hardness in the process of AG/SAG grinding is noted for sample No.1, the lowest – for sample No.5.

The values of modified Bond ball mill work index for the product of AG/SAG mill varied from 18.68 to 23.04 KWh/t. The highest ore hardness in the process of ball mill grinding is noted for sample No.1, the lowest – for sample No.4. Also it is important to note, that the value of modified grindability index for sample No.1 (23.04 KWh/t) is the highest value compared to all numbers in TOMS database for the whole period of SAGDesign testing application.

As to the values for cumulative energy for grinding in SAGDesign test, the hardest ore is observed for sample 1 – 41.18 KWh/t. The lowest hardness is observed for sample No.2 – 31.12 KWh/t.

Figure 6 represents SAGDesign test analysis and estimation of applicability of this method to the ores from Aleksandrovskoye deposit. The analysis is performed using a factor of relative ore hardness (“hardness factor”), which is calculated as a ratio of specific energy for autogenous/semiautogenous grinding (W_{SAG} index) from F80 152 mm to T80 1.7 mm to a modified Bond ball mill work index BWi (W_{SAG}/BWi).

For the studied ores this hardness factor varied within the range from 0.60 to 0.79, and together with the received values of autogenous/semiautogenous grinding index (from 11.94 to 18.14 kWh/t) characterized the ores from Aleksandrovskoye deposit as favorable for the process of semiautogenous grinding. It also proved the possibility to arrange the circuit without pebble crushing.

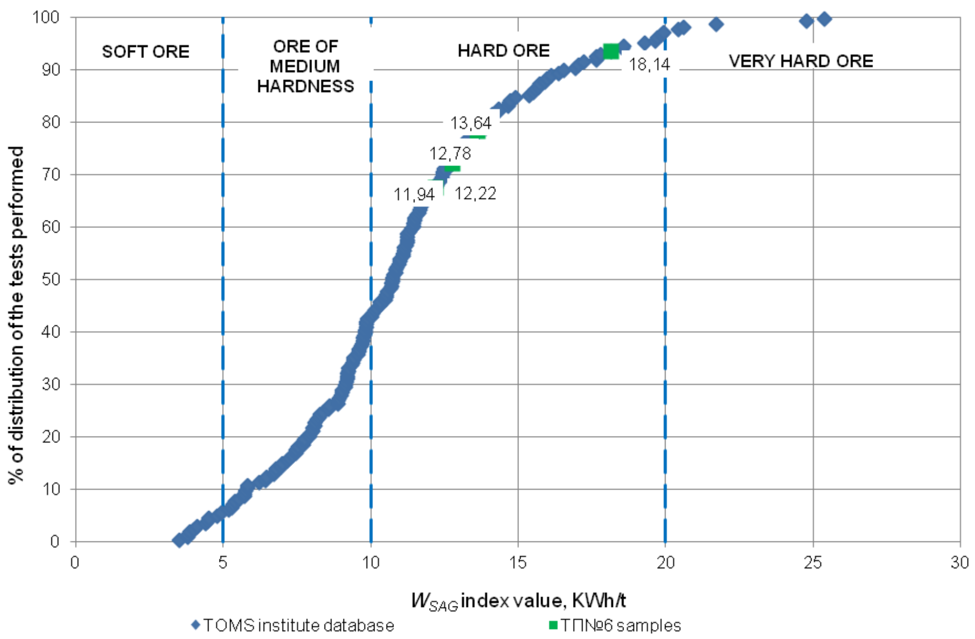

Figure 4 AG/SAG index values (W_{SAG}) for the ores in TOMS institute database

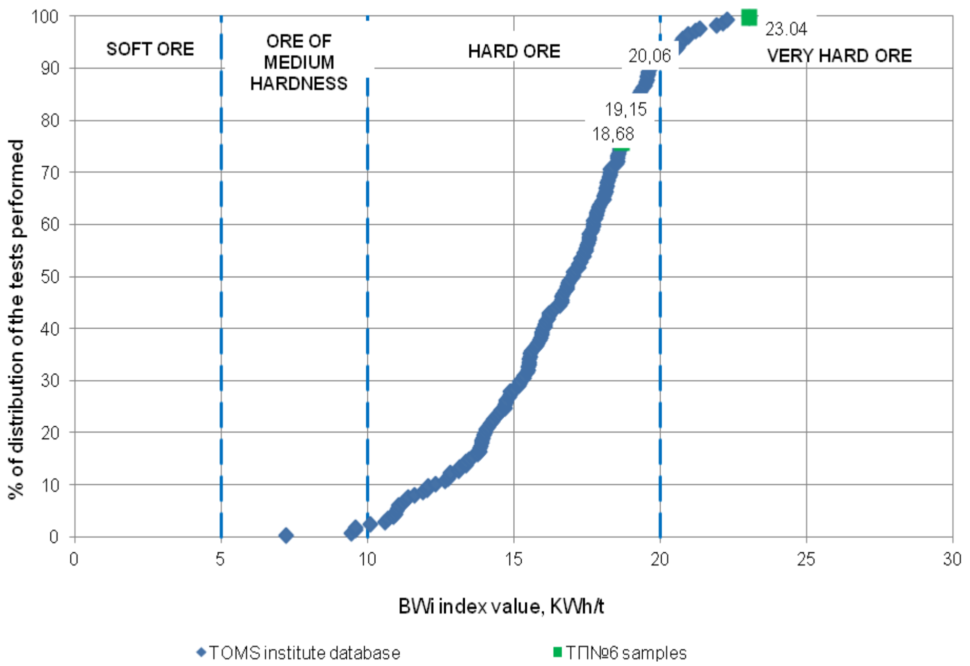

Figure 5 Modified Bond ball mill Work index values (BWi) for the ore samples in TOMS institute general database

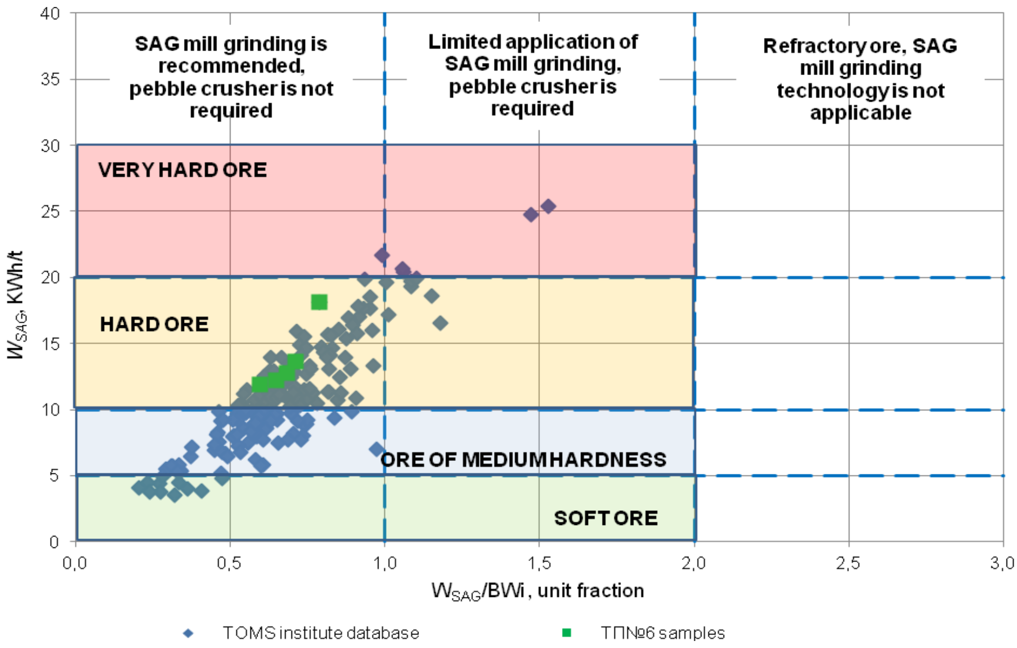

Figure 6 Relative hardness factor values in relation to AG/SAG index for the ore samples in TOMS institute general database

According to the accomplished studies it is concluded that the ores from Aleksandrovskoye deposit are considerably hard for AG/SAG mill and ball mill grinding.

MILL SIZING AND SELECTION

The grinding equipment was sized and selected based on SAGDesign testing results. The following input data were accepted in calculations:

- hourly throughput of the mills on dry ore – 91.15 tph
- ore specific gravity – 2.77 g/cm^3
- SAG mill feed size – 80% 152 mm
- target grind size – 90% 71 μm (80% 50 μm)
- AG/SAG index (W_{SAG}) – 15.89 KWh/t (from F80 152 mm to T80 1.7 mm)
- Bond ball mill work index (BWi) – 21.09 KWh/t (from F80 1.7 mm to P80 106 μm – test results) or 26.03 KWh/t (from F80 1.7 mm to P80 50 μm – design size)

Table 3 contains parameters of recommended mills. This table also contains information about the actually installed mills for comparison, these parameters almost coincide with those suggested in SAGDesign report. Outotec mills are applied at the plant.

Table 3 Recommended and installed grinding equipment

Parameter name	Mill type / Option name			
	SAG mill		Ball mill	
	calculated	actual	calculated	actual
Diameter, m	6.7	6.7	4.5	4.5
Effective grinding length, m	3.05	3.1	6.81	6.8
Effective length/diameter ratio	0.46	0.46	1.51	1.51

Mill calculated volume (with lining), m³	~100	102.8	~100	105.7
Weight, tonnes	-	382.5	-	355
Lining type	-	metal	-	rubber
Lining thickness, mm	-	100	-	100
Mill rotation speed, rpm	12.4-13.2	10.7-13.2	15.2	15.2
Mill rotation speed, % of critical	75-80	65-80	75	75
F80 feed size, mm	152	152	0.65	0.43-0.52
T80 / P80 discharge size, mm	0.65	0.43-0.52	0.05	0.07-0.1
Discharge grate opening size, mm	25	25	-	-
Grate effective cross-section, %	-	9.4	-	-
Material charge of mill, % volume	<26	25-35	35-40	35-40
Media charge of mill, % volume	10	10-14	35-40	35-40
Media diameter, mm	100-120	100	40-60	60
Media consumption, kg per tonne of head ore	1-1.5	1.0	2-3	1.4
Motor power, KW	2300	2300	2100	2100

The mills are equipped with Indar asynchronous motors with phase-wound rotor (WRIM). Motor Liquid Resistor Soft Starting System (LRS) is applied for a smooth start of a mill. Hypersynchronous system (SER) for variable speed smooth adjustment is additionally installed at the SAG mill drive.

PLANT OPERATING PARAMETERS

The plant operated under the supervision of mine specialists during the first months. Afterwards a survey of grinding section was performed together with TOMS specialists. The results of the process flowsheet survey showed that plant capacity was considerably higher than design value (by over 25%) because of improper operation of conveyor scales.

The plant officially treated over 125,000 tonnes of ore over October and November of 2013, average hourly throughput was 115.9 tph (design throughput – 91 tph).

Over the first months of operation the plant treated mainly wet argillaceous ores, this was accompanied by difficulties in storage and transportation. The situation became worse in winter season at temperatures below zero. Nevertheless SAG mill availability factor was relatively high – 91.2%.

Final grind size of the ore at the plant was 80-85% -0.071 mm which is lower than the target value (90.0%). Bond index for the ore during this period was just 17.0-17.5 KWh/t, which is lower than the index applied for ball mill selection.

Among the reasons for not getting the target grind size were the following:

1. Overestimated plant capacity due to incorrect measuring (conveyor scales).
2. Insufficient steel charge to the mills.
3. Instable operation of pump-hydrocyclone unit.

4. Steel media diameter was too big (actual size – 60 mm, compared to 30-40 mm – recommended).

Steel media consumption for SAG mill was 0.8 kg/t, for ball mill – 1.1 kg/t. Specific energy consumption was 13.8 KWh/t for SAG mill and 13.6 KWh/t for ball mill without taking into account the product grind size.

Sampling was carried out in order to determine particle size distribution of the ground and classified products. A graph was plotted based on the sampling results (Figure 7), qualitative and quantitative flowsheet was calculated. Additionally screening/classification efficiency and other parameters were calculated.

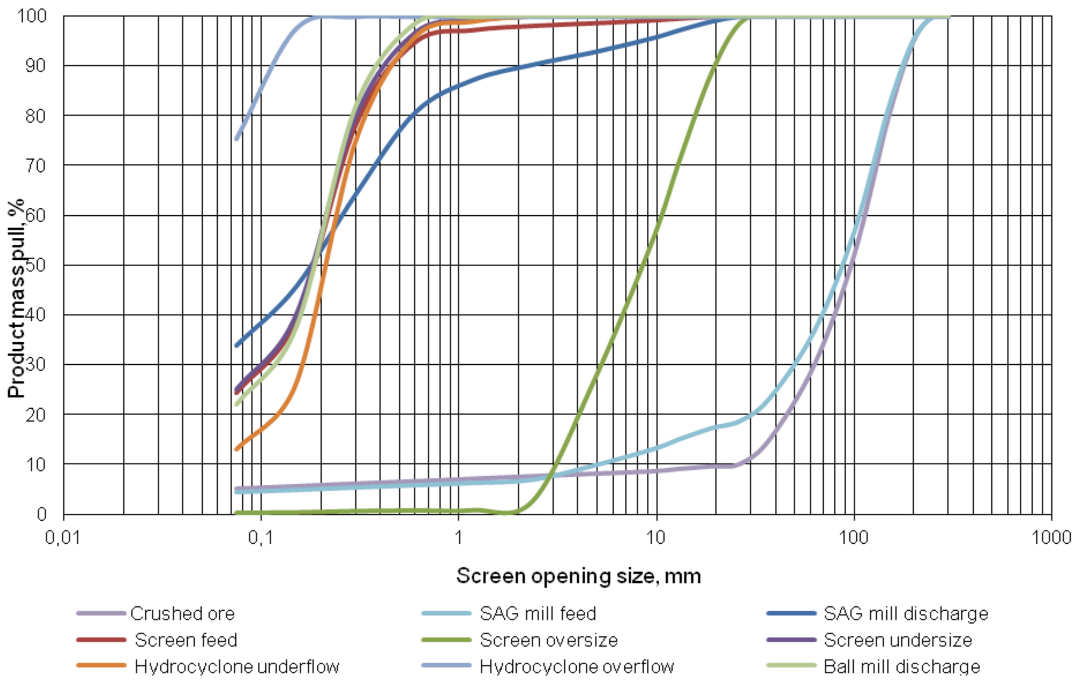

Figure 7 Grinding products particle size distribution

It was determined that SAG mill circulation load was equal to 10-11%.

Screening efficiency at 2 mm opening size was 72-88%. Fine fraction content in oversize product was not considerable – 1.7-3.1%.

SAG mill specific capacity for 71 μm size was 0.31-0.41 t/m³h, which is higher than the design value – 0.26 t/m³h.

High circulation is noted for the ball mill, considerably exceeding the target value (377-418% – actual, 285% – in design flowsheet). Meanwhile classification efficiency in hydrocyclones for 71 μm size fraction was relatively high – 52-55%. 71 μm size fraction content in hydrocyclones underflow was low – about 10.8-12.4% (13% – predicted value).

After sampling it was determined that 71 μm size fraction content in ball mill discharge was much lower than it was predicted by design flowsheet (21.1-21.3% – in fact, 33% – in design flowsheet).

Ball mill specific capacity for 71 μm size was 0.48-0.51 t/m^{3}h corresponding to design value (0.52 t/m^{3}h).

AG/SAG and ball mill work indices were calculated based on the data of grinding products particle size distribution and classification. W_{SAG} index was 6.4-6.9 KWh/t, and BWi was 24.5-28.0 KWh/t based on the plant statistics.

Calculated Bond Work index exceeds the maximum value of earlier studied ore samples (23.04 KWh/t). It was revealed during the plant survey that too large balls were applied for the ball mill. Smaller balls were recommended along with maintaining the ball charge at the level not lower 35-40% of the total barrel volume. These actions should help the plant in reaching the target grind size.

DIFFICULTIES AT THE INITIAL STAGE OF PLANT OPERATION

Fault in design of lining was revealed at the initial stage of SAG mill operation. The lifters did not raise the ground material properly resulting in having the slurry at the level of feed trunnion. This in its turn led to slurry spilling at the feed end and fast wear of the sealing. In the end it resulted in the necessity of the plant shutdown and repair work accomplishment. Figure 8 shows the spilling of slurry from the feed end.

Plant engineers conducted an industrial experiment for checking the modified lining design (Figure 9). During another mill shutdown the engineers replaced the sealing and installed wooden wedges in the grate openings (70x70 mm) imitating lifters' operation.

Figure 8 Slurry spilling from the mill feed end

Figure 9 Installation of wooden wedges imitating lifters' operation

After installing the wooden wedges slurry spilling was not observed during several days. This successful application of wooden wedges proves the necessity to change the lining and lifters design. Plant engineers developed respective drawings for new lining and placed an order to a manufacturer.

Among other small issues that arose at the initial period of operation were wet ore freezing at the feeder when winter started (it is characteristic of all northern regions), issue with pump-hydrocyclone unit adjustment, and troubles with slurry splitting before screening due to incorrect placement of the splitter.

CONCLUSIONS

Processing plant at Aleksandrovskoye deposit is a good example of design starting from ore sampling and research to equipment arrangement and commissioning. From the plant start-up and during this paper preparation, no considerable design nor technological errors were noted at the plant. Plant commissioning was accomplished within short terms.

In spite of the difficulties arising during the first months of operation at any processing plant, gold-processing plant at Aleksandrovskoye deposit reached and went beyond design capacity.

At the moment of this paper preparation the issue with receiving the required hydrocyclone overflow size by means of ball mill steel charge optimization is being solved at the plant. The issue with SAG mill lining improvement for faster slurry discharge from the mill is being solved as well.

The results of the process flowsheet survey showed that conveyor scales underestimated the actual hourly throughput (~ 25%) during the first months of operation. Undoubtedly this was one of the factors leading to not getting the required grind size. After scales calibration and decrease of hourly throughput down to design value the required hydrocyclone overflow size is expected.

The experience of plant operation confirms that the decisions in equipment sizing according to SAGDesign Consulting Group method were correct. The method confirmed its applicability for hard ores refractory to grinding.

Flowsheet analysis during the first months of operation showed that after technological parameters optimization the plant should reach the design capacity and target grind size. The power of the selected mills is sufficient.

Next papers will describe a detailed analysis of the statistical information about plant operation. Additional testing is planned, which will help in comparing laboratory testing data with the actual grindability indices.