University of Belgrade,
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XVI International Mineral Processing & Recycling Conference

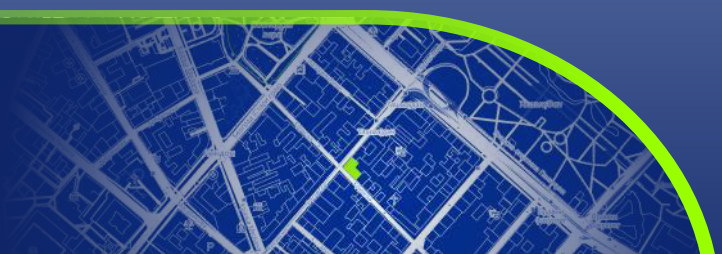
2025 IMPRC

INTERNATIONAL MINERAL PROCESSING & RECYCLING CONFERENCE

Proceedings

Editors:
Zoran ŠTIRBANOVIĆ
Milan TRUMIĆ

28-30 May 2025
Belgrade, Serbia



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NEW SAG-BALL MILL AND FLOTATION LINE FOR RECONSTRUCTING OF "ZLETOVO" FLOTATION PLANT-PROBISHTIP, NORTH MACEDONIA

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ABSTRACT – "Zletovo" Lead and Zinc Flotation Plant has existed for more than 50 years and for the future profitable work of "Zletovo" Mine, reconstruction is necessary to increase the annual capacity of the mine production and ore processing from 150 to 350 kt/y, as well as increase the technological quantitative-qualitative results. To achieve those goals, in the current reconstruction of "Zletovo" Lead and Zinc Flotation Plant, with including a "New SAG Ball Mill and Flotation Line" is expected to be achieved replacement of the existing old and dilapidated crushing, grinding and flotation as well as and to increase the technological quantitative-qualitative results. The current reconstruction of "Zletovo" Mine, is meant to increase the mine's annual capacity and ore processing by introducing the "New SAG-Ball Mill and Flotation line", with an investment of up to US$15M, the annual profit will reach up to US$25M or more.

Keywords: SAG-Ball Mill, Crushing, Grinding, Pb-Zn Ore, Concentrates.

INTRODUCTION

The processing of ore through flotation plants is a critical operation in the mining industry, particularly in extracting valuable minerals [1]. Many plants are undergoing substantial upgrades to meet the growing demands of mineral processing efficiency and address the challenges posed by increasingly complex ore characteristics. One such project is the reconstruction of "Zletovo" flotation plant, a key facility in the mineral processing sector.

"Zletovo" flotation plant, located in the northeast part of North Macedonia, has long been a vital player in the processing of lead and zinc. However, as global mining operations evolve, the plant needs modernization to maintain competitive and efficient operations. This paper discusses the implementation of a new Semi-Autogenous Grinding (SAG) mill and a comprehensive flotation line as part of the plant's reconstruction process [2].

These technological advancements are designed to significantly enhance grinding, flotation and overall mineral recovery, while optimizing energy consumption and operational costs [3].

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"Zletovo" Mine (Ore Mining & Processing) dating just before the II-nd World War, with the first oldest flotation plant (two sections I-II only with lead flotation) and annual ore capacity up to 25 kt/y. In the period after the II-nd World War, in 1953, it was introduced a new flowsheet with additional zinc flotation.

The reconstruction of the brand-new building flotation plant "Crushing, Grinding and Flotation" (primary and secondary crushing with screening and two identical: I-II sections of grinding and flotation of lead and zinc) for an annual ore capacity up to 55 kt/y, began in 1972 and continued successfully until 2005, i.e., due to the insolvency of "Zletovo" Mine [4,5].

After 2006, the new private concessionaire decided to work only with the "I-st Section, grinding and flotation of lead and zinc," which, without any major reconstruction, still exists and works today [8].

Nowadays, is necessary development of "Zletovo" Mine for its future profitable work through the relevant current reconstruction with introduction of the "New SAG-Ball Mill and Flotation Line", II-st Section, ball mill and flotation of lead and zinc.

"Zletovo" Flotation Plant, according to the current reconstruction with introduction of the "New SAG-Ball Mill and Flotation Line", should increase the annual capacity of the mine production and ore processing from 150 to 350 kt/t, as well as to increase technological quantitative - qualitative results.

In general, according to the current reconstruction with the „New SAG-Ball Mill and Flotation Line", it is foreseen:

- Replacement of the existing old and dilapidated "Crushing", with a new single parallel primary crusher "Jaw Crusher" and primary open "Stockpile";
- Replacement of the existing old and dilapidated "Grinding", with a new parallel "SAG-Mill Line" and II-nd Section existing ball mill;
- Replacement of the existing old and dilapidated "Flotation", with a new parallel "Flotation, II-nd Section flotation of lead and zinc line";
- Increasing the technological quantitative-qualitative results of the flotation lead and zinc concentrate.

FLOTATION PLANT RECONSTRUCTION

The reconstruction of the flotation plant with introduction of the "New SAG-Ball Mill and Flotation Line" will solve the follow problems:

Crushing: The new single primary „Jaw Crusher" for crushing to the definitive ore size up to F_{80} = 180 mm and new „Stockpile", with a capacity up to 6 kt, efficient for the wet ore up to 10-12% H_2O and content up to 12-15% of kaolin.

Grinding: The flowsheet of the "New SAG-Ball Mill Line" with II-nd Section existing ball mill *(with a capacity up to 56 t/h, grinding the material up to 65% of class - 200# (74μm), efficient for the optimal grinding results)* are shown in Figure 1.

Flotation: The flowsheet of the "New SAG-Ball Mill Line", II-nd Section flotation of lead and zinc *(with a capacity up to 56 t/h, efficient for the optimal technological quantitative-qualitative results)* are shown in Figure 2.

The metal balance of the flowsheet "New SAG-Ball Mill & Flotation Line" is shown in Table 1.

Table 1 Metal balance of the flowsheet "New SAG-Ball Mill & Flotation Line"

Product	Mass %	Pb %	Zn %	Ag g/t	R% Pb%	R% Zn%	R% Ag%
Ore	100.00	4.30	2.20	40.00	100.00	100.00	100.00
Conc. Pb	5.43	76.00	2.50	589.15	96.00	6.17	80.00
Conc.Zn	3.44	1.05	55.00	87.21	0.84	86.00	7.50
Tailings	91.13	0.15	0.19	5.49	3.16	7.83	12.50

The "New SAG-Ball Mill and Flotation Line" is planned to be solved by new equipment and modern efficient flotation cells for:

- Rougher and scavenger flotation of lead and zinc, type "RCS/OK 10", volume 10 m^3 and for cleaning the concentrates, type "RCS"/"OK-Concorde Cell", volume 3 m^3, with regrinding of the all-middling's flotation products" by new "VertiMill-Classification" [3].

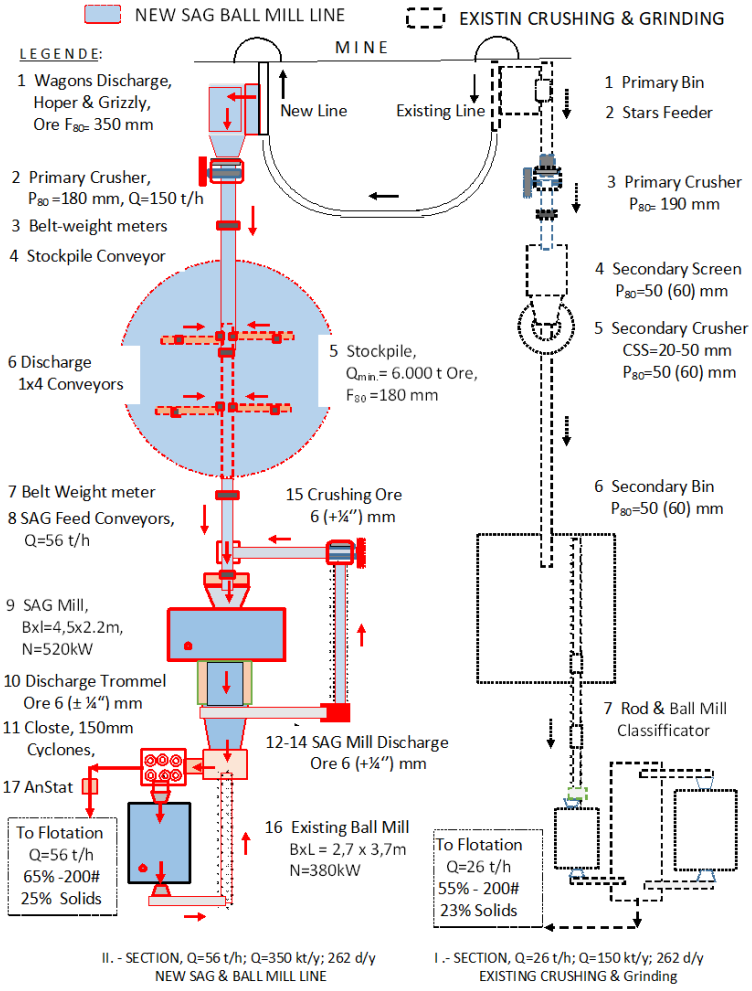

Figure 1 Flowsheet "New SAG-Ball Mill Line", II-nd Section existing ball mill

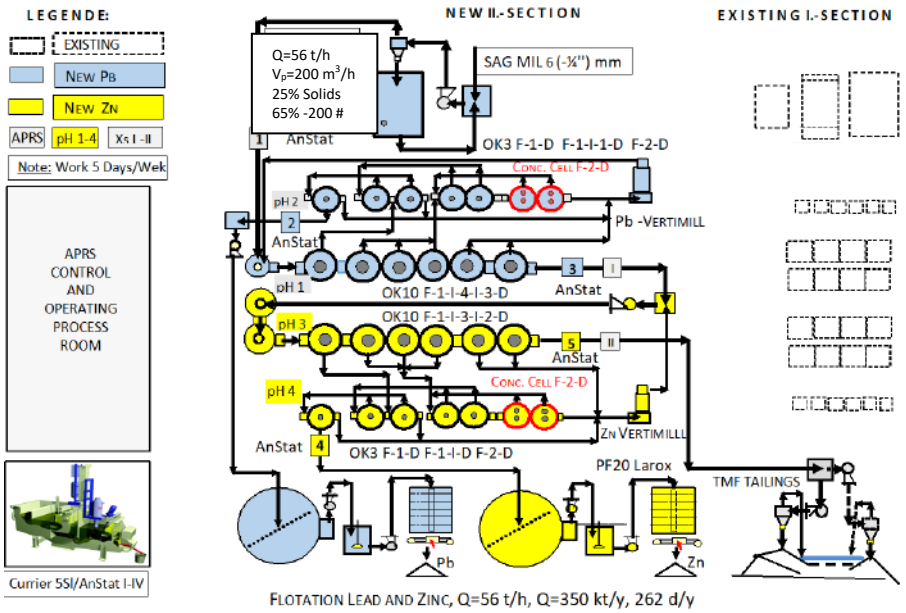

Figure 2 Flowsheet "New ,SAG-Ball Mill Line", II-st Section Flotation of Lead and Zinc

TECHNO-ECONOMICAL CRITERION

The techno-economic criterion was made according to the current following comparative analyses:

- comparative results of ore capacity and effective working days, Table 2;
- comparative results of ore normative material, Table 3;
- comparative of quantitative-qualitative results, Table 4; and
- comparative results of calculated by the **ore value (US$/t).**

Table 2 Comparative results of ore capacity and effective working days

Criterion	Old	New	Diference
Ore Mining			
Anual, Q	150 kt/y	350 kt/y	(+) 200 kt/y
Effective Work Days, T	312 d/y	312 d/y	(±) - d/y
Ore Processing			
Hourly, Q	< 26 t/h	56 t/h	(+) 30 t/h
Effective Work Days, T	262 d/y	262 d/y	(±) - d/y

Table 3 Comparative results of ore normative material

Normative	Old	New	Diference
Mine	92.40 US$/t	58.00 US$/t	34.40 US$/t
Flotation	34.20 US$/t	19.80 US$/t	14.40 US$/t
Total	126.60 US$/t	77.80 US$/t	48.80 US$/t

Table 4 Comparative technological quantitative-qualitative results

Criterion	Old	New	Diference
Quality			
Lead Concent.	72.00% Pb 4.20%Zn	76.00Pb% 2.50Z%	(+) 4.00Pb% (-) 1.70Zn%
Zinc Concent.	1.80%Pb 50.00%Zn	1.05Pb% 55.00Zn%	(-) 0.80Pb% (+) 5.00Zn%
Ag/Lead Concent.	450.00 g/t Ag	589.15 g/t Ag	140.00 g/t Ag
Recovery			
Lead Concent.	92.00% R-Pb%	96.00 R-Pb%	(+) 4.00 R-Pb%
Zinc Concent.	71.00% R-Zn%	86.00 R-Zn%	15.00 R-Pb%
Ag/Zinc Concent.	62.00% R-Ag%	80.00 R-Ag%	18.00 R-Ag%

Comparative results of **ore value (US$/t)** is calculated by the following equality:

$$\boldsymbol{VO} = \mathbf{Y_C}\,(\boldsymbol{P_M}\cdot\ \boldsymbol{\beta_M}\cdot \mathbf{RS_M}\ - \mathbf{TC_S} - \boldsymbol{RC_S} - \mathbf{TC_T})\ \ (\boldsymbol{US\$/t});$$

The symbols in the equality stay for:

V_O - value ore (US$/t);
Y_C - masse concentrate (%);
P_M - prices meatal "LME" 2024
β_M - content metal in concentrate (%);
RS_M - recovery metal in metallurgy (%) ;
TC_S - smelting expenses (US$/t);
RC_S - refining expenses (US$/t);
TC_T - transport expenses (35.00 US$/t);

	Lead concentrate	**Zinc concentrate**
RS_M	Pb >60; 95.0%;	RS_M Zn >51%, 85.0%;
RS_M	Ag >50g/t 95.0%;	RC_S Ag 0.02 US$/g;
TC_S	98.00 US$/t;	TC_S 160.00 US$/t;

CONCLUSION

Regarding to the relevant current reconstruction of "Zletovo" Lead and Zinc Flotation Plant with the "New SAG Ball Mill and Flotation Line", the following can be concluded:

- The "New SAG-Ball Mill and Flotation Line" under the existing current conditions ***(effective* work *days)*** should increase the annual capacity from 150 to 350 kt/y;
- The "New SAG-Ball Mill and Flotation Line" is an essential because it can be built ***(in a parallel***) without a new building and any major construction works, i.e. without interruption of the current production of "Zletovo" Mine;
- The "New SAG-Ball Mill and Flotation Line" under the new current conditions ***(annual and hourly ore capacity)*** should achieve the following technological and economic results:
  - Increases of ***annual ore capacity, Q, up to (+) 200 kt/y;***
  - Increases of ***flotation hourly capacity, Q, up to (+) 30 t/h;***
  - Decreases of ***ore normative material-US$/t, up to (-) 48.80 US$/t;***

- Quality of the concentrate:

  - Lead concentrate ***up to >76% Pb, >600 g/t Ag, and < 2.5% Zn;***
  - Zinc concentrate ***up to >55% Zn and < 1% Pb.***

- Recovery of the concentrate:

  - Lead concentrate ***up to >96 R%Pb% and >80 R%Ag%;***
  - Zinc concentrate ***up to >86 R%Zn%.***

The new relevant current reconstruction of "Zletovo" Mine, by introducing of the ***"New SAG-Ball Mill and Flotation Line",*** with an investment of up to US$15M, the annual profit will be increase ***up to US$25M or more***.

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