IMPROVING THE EFFICIENCY OF THE METHODOLOGY PHYSICAL MODELING CONE CRUSHER PROCESSES

Komilov. S.I[1], Normurodov E.I[2], andKosimbetov B.E[3]

[1]Tashkent State Transport University, Tashkent, Uzbekistan

[2]Karakalpak State University, Karakalpakistan, Uzbekistan

ABSTRACT. *The article a software for automated cone crusher control system, that allows to integrate a set of interconnected technological units in the control of one hardware, controller and human-machine interface on the touch panel in the operator station.*

Liner wear has been a subject of research for a long time in the mining and communication industry and academia. While most of the efforts have been related to understanding wear rate and mechanisms, few have been targeting the actual effect it has on process operation and machine performance.

Such strategies are among the most reliable ways to improve the operating performance of a process without changing its flowsheet (Garcia et al., 1989; Lotter et al., 2018; Svensson and Steer, 1990). Control strategies seek to optimize some type of performance index or goal (production rate, product quality) by considering a set of operational, financial or environmental constraints (Bhadani et al., 2020)

1 INTRODUCTION

Rocks, ores, and their sub products have always been of great importance for civilization. For example, as mentioned in De Re Metallica - one of the oldest known book about mineral processing - back in the Medieval Age, male slaves and peasants, the 'breakage section', swung heavy mallets and hammers to break rocks to produce gravel or extract metals. Women and children, the 'classification section', separated the product of interest from the gangue using crafted screens on riverbeds. Gravel and aggregates were used to build castles, churches, and watchtowers, and metal was melted and transformed into silverware, ornaments, weapons. We have come a long way regarding technology and labor rights; however, the fundamental need to break rocks to provide raw material for other industries still remains, and is expected to remain in the foreseeable future.

The rock is removed from the ore body by drilling followed by blasting, and then loaded and processed for primary crushing, because the blasted rock can be very large and cannot be transported on a conveyor. The primary crushed stone is now large enough to fit on the conveyor (0-220 mm).

Thereafter the rock is again crushed in a series of crushing stages using, jaw crushers, cone crushers, HPGRs, or in some cases AG- or SAG-mills. How many, what type and configuration vary from plant to plant. After crushing, the fine gravel is, in most cases milled to final size and a powder, for example using tumbling mills. This powder is then transferred to a separation process where the gangue rock and the valuable minerals are separated, in general terms called concentration.

A more detailed description of how minerals processing plants are built up is presented by Wills [4]. The concentrators or processing plants are huge installations, as can be seen in Figure 1.2, requiring significant investments and are intended to be used for a long time (several decades). The goal of a plant is to process as much as possible or desired to the highest quality possible. Every hour that a plant is not operating, production volume is lost, and there is no way of getting lost production back.

2 Materials and Methods

This research concerns parts of the processing chain, and it is, therefore, vital to see the bigger picture in terms of the processing plant. Two simplified flow sheets are shown in Figure 1.3 and 1.4 to illustrate examples of two different processes. **In Figure 1.3,** the process contains four stages (1-4) of communication with classification. This could be a typical setup for a minerals processing concentrator.

The product from the pictured flow sheet continues to a separation process and possible further regrinding if needed. **In Figure 1.4 a** flow sheet for a SAG circuit is drawn. This is an alternative to the more crusher focused flowsheet in **Figure 1.3**. Pebbles crushing is a popular addition to traditional SAG circuits in the way it is illustrated in **Figure 1.4**. Especially since the general trend is that ores are getting harder and it, therefore, becomes nearly impossible to grind down the pebbles.

Figure 1.1: A minerals processing plant and an overview of the conveying system between crushers, screens and storage units.

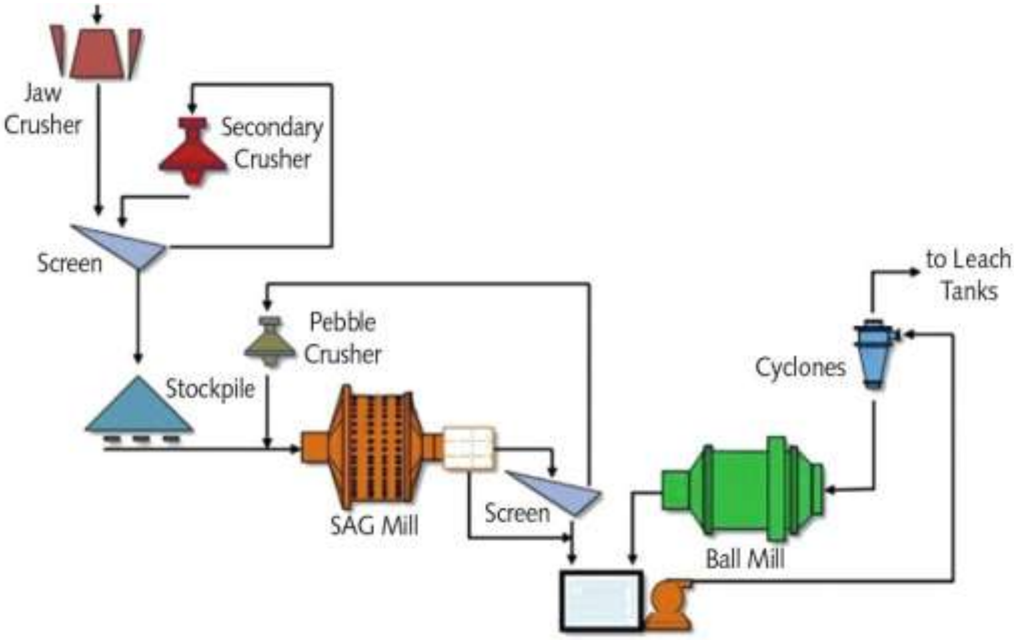


Fig. 1.2 shows an overview of the average copper content in the ore beneficiation plants worldwide; this has decreased by almost 0.7 % Cu/t ore to 0.9 % Cu/t ore since 1990.

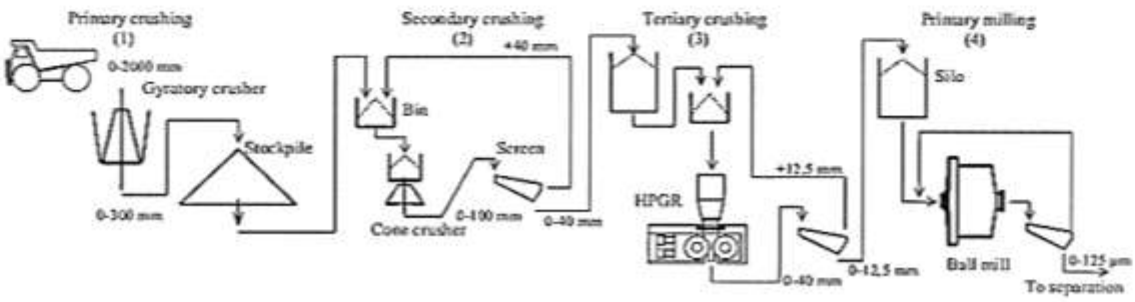


Figure 1.3: A simplified and ideal flow sheet with four stages of communication and three classification stages.

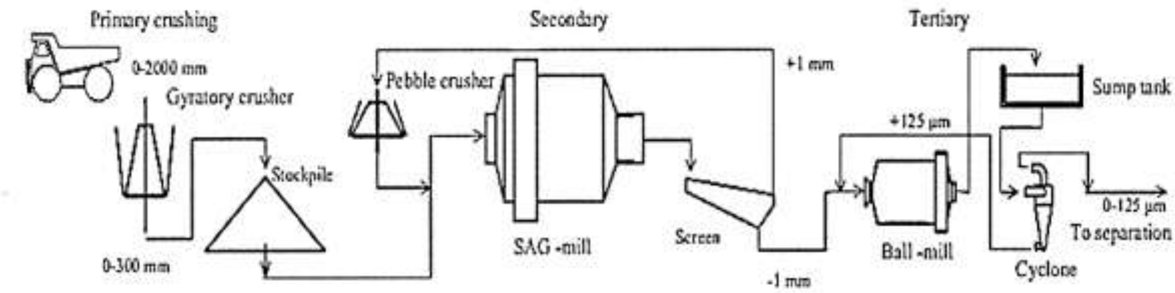
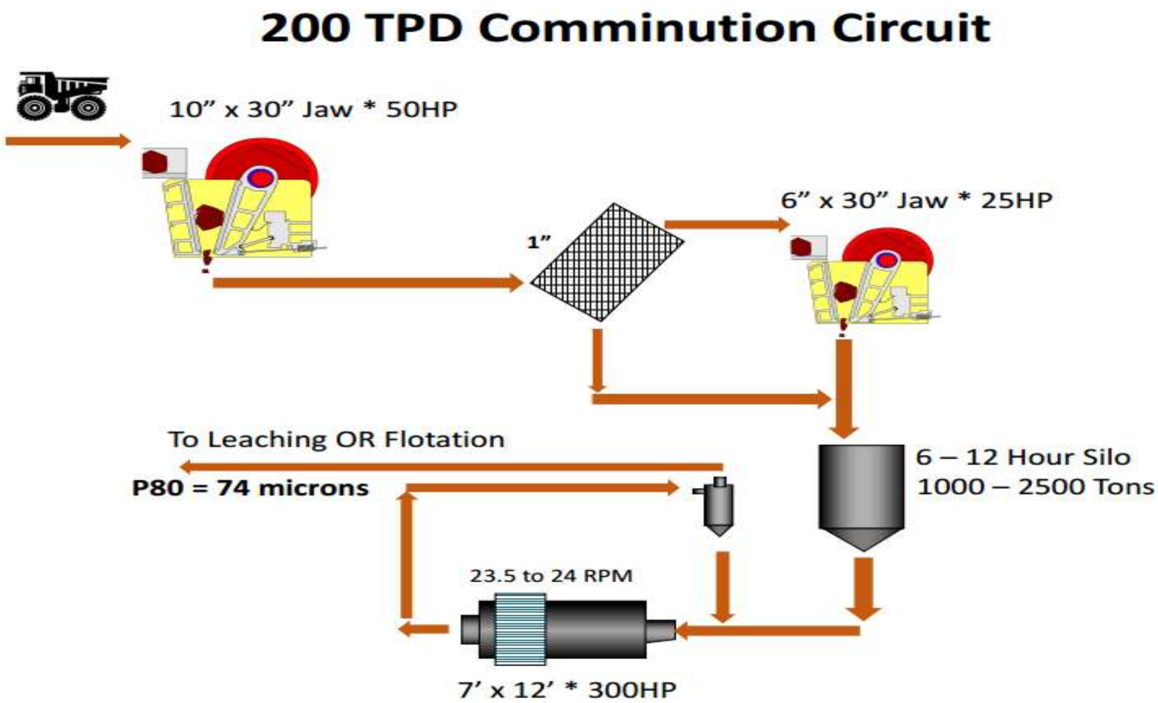


Figure 1.4: A simplified and ideal flow sheet for a SAG-mill circuit with regrinding(ball mill) and pebbles crushing.



At 100% operating time, the 250 x 750 mm primary jaw crusher should be capable of crushing 300 TPD at a discharge product of <1.5″ while the smaller 150 x 750 mm secondary crusher should take the 1″ screen oversize and produce <3/4″ at a rate >200 TPD. My design assumes the preceding vibratory screen will reduce the mass feeding the small gap jaw by 50%. I based this idea on the old multi-jaw concept patented way back for fine crushing using low cost jaw crushers. See this Multi Jaw for fine crushing concept.

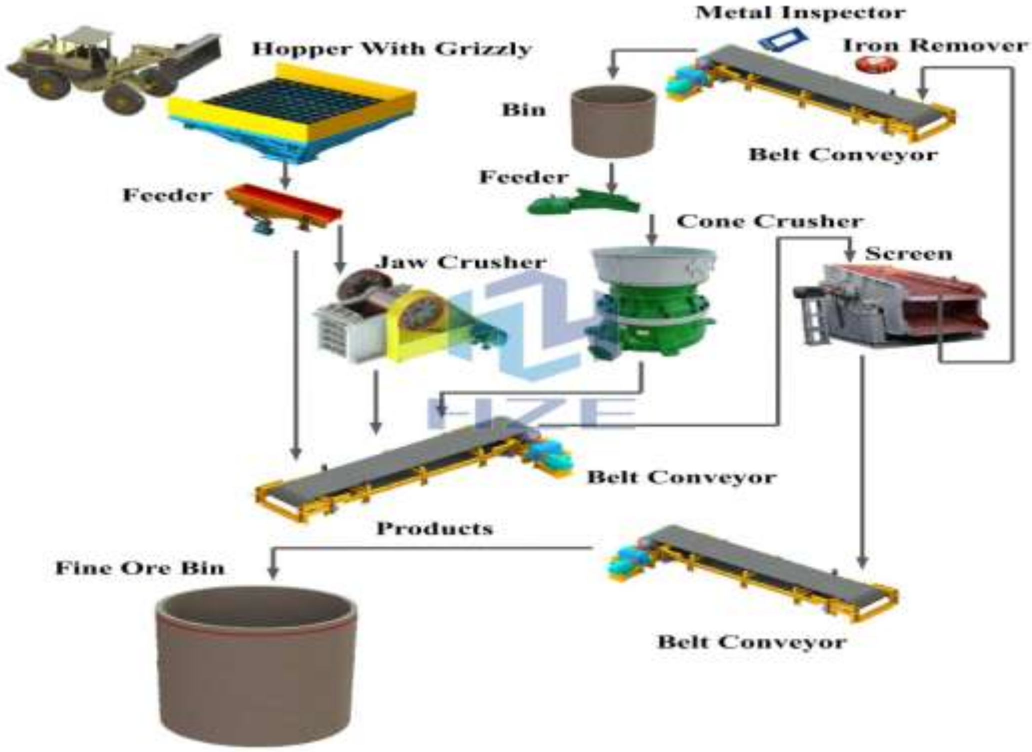


Figure 1.5. Closed circuit of two crushing stages

3 MODELING

A model is a way of describing something real in a simplified form. Models are developed in the discipline of modeling. In this study, mathematics is used as a modeling tool to describe reality. A model is never perfect because it starts with assumptions as part of a simplified description of real phenomena. Modeling exercises can go on indefinitely, trying to develop the perfect model.

Traditionally modeling and simulation of comminution systems have been carried out in steady-state. This includes simulations software such as, JKsimMet[2], AggFlow[3] and ModSim[4]. This development of simulation platforms for communition circuits started before computers were as powerful as they are today.

This is one of the reasons for using steady state simulations rather than time varying, dynamic simulations. Whiten [4] presented simulations of a closed crushing circuit and Ford and King [1] presented solutions to simulate entire plants, from crushing to separation. The techniques presented in these papers among others have contributed to developing the above mentioned steady state simulation software.

A generic block model is shown in Figure 1.6, including notation for, Feed (F), model parameters (p), model inputs (u), internal variables (x), Product (P) and model outputs (y).

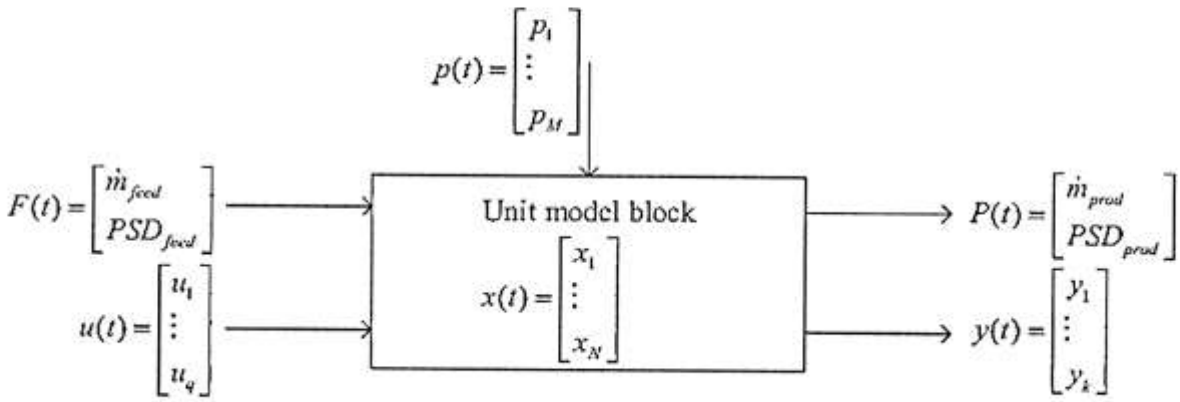


Figure 1.6. An example of a unit model with the different variables and parameters associated with a model.

For research purposes, it is practical to develop models in a stand-alone platform, where there is full access to the source code of the models and the setup. The modeling work within this research builds mainly upon the work of Evertsson, Asbjörnsson and Bengtsson [1,4]. The environment used for model development and simulation is MATLAB and Simulink, mainly for historical and practical reasons. The end goal with the models is to make as accurate models as possible.

The models are aimed to be used in time dynamic simulations, implying that they are stepped one time step at the time and with changing inputs. This is very different compared to a steady-state simulation, where the simulation model is iterated until mass balance is found. Steady-state is an equilibrium state that can be found with dynamic simulations as well, however with all the variations present in real-world plant, the actual existence of steady-state for a longer time period is unlikely.

This research focuses on process models, mostly time dynamic, the requirements on those are as follows:

[2]https://jktech.com.au/jksimmet

[3]https://www.aggflow.com/aggflow-design

[4]http://www.mineraltech.com/MODSIM/

• Run faster than real-time when simulated.

• Respond to changes in the process, both machine settings, and operating conditions.

• Be predictive and possible to operate in a specified range of conditions.

Industrial process control

The research approach in this work can be regarded as both exploratory as well as constructive in the sense that even though a specific case is investigated, novel knowledge coupled to both fundamental crushing operation as well as DEM modelling has been harvested in the process. The work in this paper covers the following sections:

3.1. Mobile crushing and screening plant with cone crusher

Cone crushers are the most effective for medium and fine crushing of strong and highly durable rocks. They carry out crushing continuously due to the rotation of the eccentric conical rotor - the "crushing cone" inside the outer stationary cone.

Cone crushers use continuous rotation instead of oscillations; unlike jaw crushers the change in clearance is made not simultaneously along the entire width of the gap, but alternately by its variation along the length. The working clearance in the cone crusher varies not simultaneously along the entire width as in the jaw crusher, but continuously along a circle, helping to improve the quality of crushing. The input and output gaps in the cone crusher are in the form of concentric rings. The maximum and minimum size of the output slot is set by the adjusting device.[7]

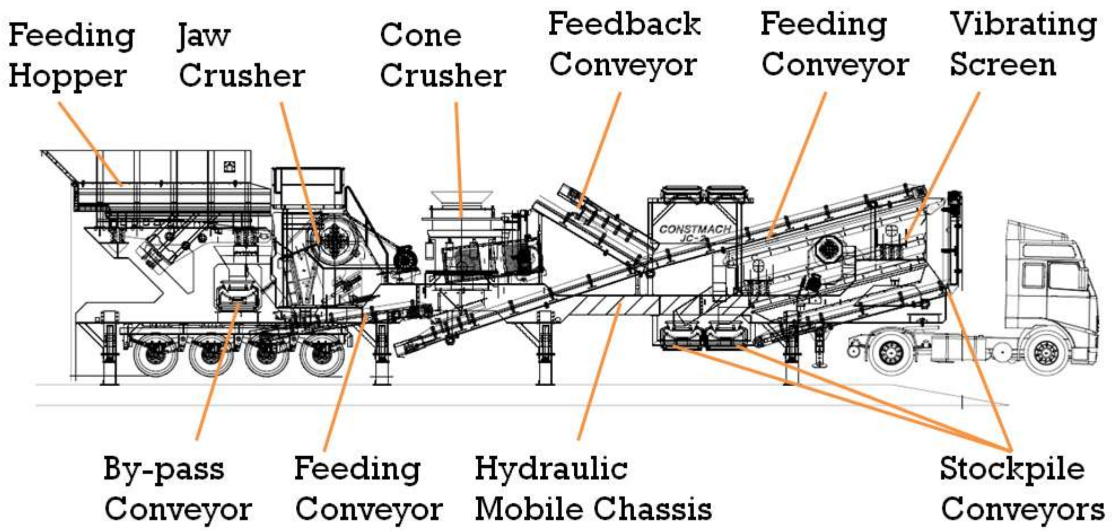


Figure 1.7. Metso NW220GPD mobile crushing and screening plant with Nordberg GP220 cone crusher

Figure 1.8. Metso NW220GPD mobile crushing and screening plantwith Nordberg GP220 cone crusher

Process control of crushing circuits Process control strategies can be simple (proportional-integrative-derivative (PID) control), complex (plant wide economic model-based control), or any combination in between. Such strategies are among

the most reliable ways to improve the operating performance of a process without changing its flow sheet (Garcia et al., 1989; Lotter et al., 2018; Svensson and Steer, 1990). Control strategies seek to optimize some type of performance index or goal (production rate, product quality) by considering a set of operational, financial or environmental constraints (Bhadani et al., 2020). Moreover, process modeling simulation and control also provide a framework for fault detection, operator training, and plant evaluation. Although many works have contemplated control strategies for grinding circuits, the literature concerning crushing circuits is limited. Since grinding and crushing operate with process-specific equipment, the results observed in the former are not straightforwardly extendable to the latter. Hulth´en (2010) argued that the preference for grinding circuits over crushing circuits in the literature is due to the high intrinsic economic value of the products. Liu and Spencer (2004) mentioned that dynamic models of grinding circuit equipment are relatively mature and that researching the appropriate control of problematic units, such as

SAG/AG mills, is of interest.[6].

REFERENCES

1. R. J. Fouchee R. P. Brown C. W. Steyn. “Improving crusher performance by comparing various control strategies using a validated simulation”. In: In proceedings for the MEI 10th International Comminution Symposium (Comminution ’16) 10 (2016) (cit. on p. 16).

2. Piotr Tatjewski. Advanced control of industrial processes: structures and algorithms. Springer Science & Business Media, 2007 (cit. on p. 7).

3. WJ Whiten. “The simulation of crushing plants with models developed using multiple spline regression”. In: Journal of the Southern African Institute of Mining and Metallurgy 72.10 (1972), pp. 257–264 (cit. on p. 6).

4. Hans von Michaelis. “Real and potential metallurgical benefits of HPGR in hard rock ore processing”. In: Proceedings of the Randol Innovative Metallurgy Forum. 2005, pp. 31–39 (cit. on p. 17).

5. Gauti Asbjornsson. Crushing Plant Dynamics. Chalmers University of Technology, 2015 (cit. on pp. 6, 15, 16, 41).

6. Gabriel KP Barrios and Luis Marcelo Tavares. “A preliminary model of high pressure roll grinding using the discrete element method and multibodydynamics coupling”. In: International Journal of Mineral Processing 156 (2016),

7. Andrey Ostroukh, Nataliya Surkova, Oleg Varlamov, Valery Chernenky, Alexander Baldin. Automated process control system of mobile Crushing and screening plant. Journal of Applied Engineering Science. 2018

8. S. Yamashita, Alex Thivierge, Thiago A.M. Euz´ebio.A review of modeling and control strategies for cone crushers in the mineral processing and quarrying industries, AndreMinerals Engineering.2021