Powder Technology 288 (2016) 324–338

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Review

Survey on higher-level advanced control for grinding circuits operation

Ping Zhou *, Shaowen Lu, Meng Yuan, Tianyou Chai

State Key Laboratory of Synthetical Automation for Process Industries, Northeastern University, Shenyang 110819, PR China

ARTICLE INFO

Article history:
Received 22 April 2015
Received in revised form 6 October 2015
Accepted 6 November 2015
Available online 7 November 2015

Keywords:
Grinding circuit (GC)
Advanced control
Process operation
Operational indices
Advanced feedback control (AFC)
Basic feedback control (BFC)

ABSTRACT

Grinding circuit (GC) is the most critical production unit and it also has the highest energy consumption in mineral processing operations. The control and optimization of GC are regarded as important ways to improve product quality and production efficiency of the whole concentration process. The fundamental goal of the automation system of GC is to make the outputs of the controlled processes best follow the control set-points. Moreover, from the standpoint of process engineering, it should as well ensure that the grinding product quality and efficiency during production phase are well controlled within the optimal ranges. Those goals cannot be achieved solely at the level of basic feedback control where global operational indices are not considered. Therefore, higher-level advanced control is required for the whole grinding plant operation to achieve integrated control and optimization of the indices of control, operation and mineralogical economics. This paper overviews the available advanced control methods and technologies for improving operation of GC system based on our experiences of research and practice in this field. A brief introduction of GC and its advanced control problem for process operation are presented first. Then, a comprehensive and systematic review on the available methods and technologies of higher-level grinding advanced control is given. The emphasis of this review is on the approach of data & knowledge based hybrid intelligent advanced feedback control. Issues about the future research on the advanced control of GC are outlined when concluding the paper.

Contents

http://dx.doi.org/10.1016/j.powtec.2015.11.010
0032-5910/

1. Introduction

In the process industry, mineral processing (as shown in Fig. 1) is an important sector of metallurgy raw materials. This is especially the case in China. It is reported that 97% of the raw iron ores in China need to go through an additional complex process of beneficiation in order to further concentrate the useful ingredients in ore before metal smelting and other related processing. This is because that most iron ores in China are of low-grade, such as hematite, siderite, limonite and specularite. In the mineral processing industry, *grinding circuit* (GC) is the most critical production unit as it connects the previous crushing and the following separation operations. The operation of GC grinds the broken raw mineral material (by crushing) into finer ore particles of an appropriate granularity. Thus, useful minerals can be separated from gangue monomer and different minerals are dissociated to offer raw material for the subsequent beneficiation works. Grinding process consumes high energy and has low production efficiency. The power consumption of grinding typically accounts for about 45% to 70% of the total consumption of the entire mineral processing plant and the production cost of GC system accounts for about 40% to 60% of the total cost. Moreover, *grinding operational indices* like product particle size and grinding production are closely related to the economic and technical indices of the whole mineral processing plant [1–12].

For a long time, the control and optimization of GCs have being regarded as important ways to improve grinding quality and production efficiency as well as to enhance the economic profit of the concentrator. Problems in this subject have received growing attentions from the industry and the academia. The lower-level *basic feedback control* (BFC) technologies like PI/PID control and multivariable control are widely used to regulate grinding equipment in accordance with the desired targets [10]. However, the automation of GCs should not only make the outputs of the controlled processes best follow their set-points, but also need to ensure that the whole plant is optimally operated so that the operational indices (such as grinding particle size and efficiency during production phase) are well controlled within their target ranges. This means that the automation system of GCs should realize optimal process operation [3–5,13].

To achieve a specified overall performance of process operation, it requires decision-making and supervision at higher-levels to provide the appropriate working points for the lower-level BFC system according to the operating environment and boundary conditions. In most cases, such decision and supervision control are handled by experienced engineers and operators as shown in Fig. 1, where the detailed

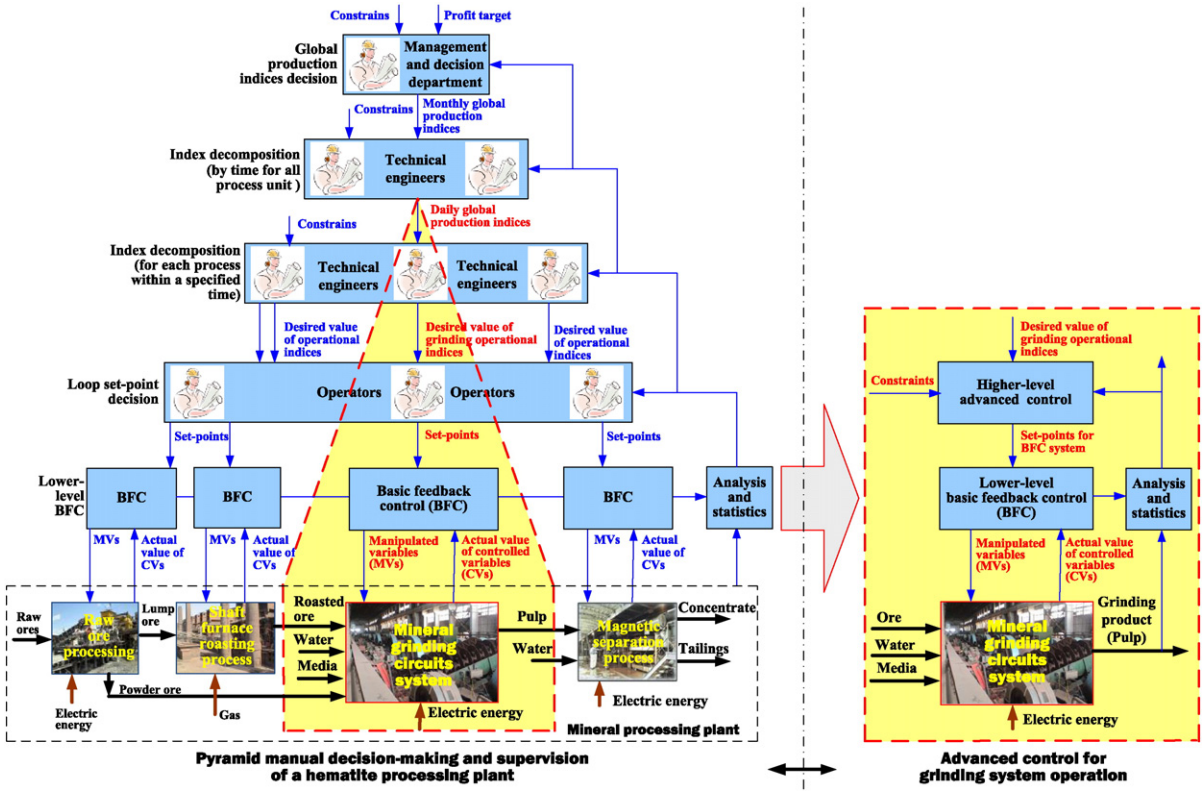

Fig. 1. Manual decision-making and supervision of a typical hematite processing plant (left) and hierarchical structure of advanced control for grinding system operation (right).