EXTENDED ABSTRACT
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PID and Predictive PID Control Design for Crushing And Screening

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Abstract: Crushing and screening processes are often regulated using relay-based on/off controls or, when controlled by PID controllers, the control design is limited to a single crusher and its proximity. The design does not necessarily consider process interactions, load disturbances and, in a wider perspective, does not treat a crushing and screening plant as an entity from feeding to product piles. This paper outlines a plant-wide process control design with guidelines for crushing and screening processes. To allow usage of conventional PID controllers, effort is placed on designing controls that aim to decouple interactions and provide a good load disturbance rejection. Sensors and actuators play a significant role in any process control and, therefore, they are also considered in this paper. The paper also introduces a new controller type, Predictive PID, and justifies its usage for regulating dead-time dominant integrating crushing processes.

Keywords: PID control, predictive, control design, crushing, screening.

1. INTRODUCTION

Crushing and screening processes conventionally have only simple on/off controls for starting and shutting down equipment. These on/off controls comprise of e.g conveyor, feeder and crusher controls. Even if there were variable speed driven actuators, such as conveyors and feeders, they are often driven at a pre-defined fixed value and changed rather infrequently. Tradionally, at its best, there are only a few automatic PID (Proportional-Integral-Derivative) controls allowing smooth and disturbance compensating regulation of process variables. However, these controls are limited to operate only within a particular machine unit, such as a crusher, not allowing co-ordination and control of consequtive machine units. The lack of plant-wide process controls in crushing and screening processes prevents from utilising the whole production capacity potential of the machinery

In the past, a lot of effort has been put on modelling single crushers which, obviously, serves a solid base for designing process controls. Crusher modelling work propably publicly initiated by Whiten (1972) and (1984) has been continued e.g by Evertson (2000), Johansson (2009) and Itävuo (2011) and (2013). There has been some publications on expanding the process control idea out of the crusher itself such as Sbarbaro (2005) and Itävuo (2012). Yet, they have limited their research on a sub-process containing a single crusher with screens and conveyors. A typical crushing plant, however, contains several crushing and screening phases which should be always considered simultaneously on a control design board.

Designing PID and PPI(D) controllers for a whole crushing plant does not require models for processes to be controlled. However, interactions and non-linearities of process variables need to be considered and, consequently, design measures to decouple them need to be taken. However, when considering tuning of PID and PPI(D) controllers, process models are significantly valuable. The process models can be used for tuning controllers and for verifying their performance and robustness against modelling uncertainties and load disturbances. Controller design even benefits from simple low-frequency models that can be created through identification tests such as presented by Airikka (2012a). A nice collection of several transient-based identification tests are given by Åström and Hägglund (1995).

The purpose of plant-wide process control design is to consider a whole crushing process from material feeding to final screening as an inter-connected process control entity. By designing process controls which utilise sensors and variable speed driven actuators, a process can be engineered to operate as a team instead of individual players. By replacing relay-based on/off controls by PID or Predictive PI (PPI) controls, process disturbances and changing process circumstances can be compensated more efficiently resulting in reduced process variations and better process performance. Plant-wide automatic process controls with decoupled disturbance impacts decrease variations allowing higher setpoints for targeted process variables. Consequently, the key performance variables, such as production and machine utilisation rate, can be drastically improved without investing a great deal in machinery itself.

In one of his break-through papers, Hägglund (1996) introduced a Predictive PI (PPI) controller for compensating dead times in delay-dominant processes. The elegant idea is to replace a derivative part of a PID controller by a predictive part which is clearly better for predicting future than derivation itselt. The other benefits of the PPI controller come through both its simple parametrisation compared to a Smith predictor and its applicability to integrating processes without any modifications. In this paper, the usage of derivation part together with a PPI controller is justified through performance improvement achievements in real implementations for crushing and screening processes. The derivation term does not work for compensating dead time but it works, as traditionally, for reacting on changes in the controlled process output helping the control loop act better than without. And, when applied to integrating and dead-time dominant processes, the PPID controller gives a bigger stabilisation space for the controller tuning parameters allowing tighter tuning. A real crushing process control case for showing the applicability of the PPID is given in this paper.

Pre-requisites for succesful process controls are reliable and accurate sensors and actuators that can be operated over a wide range with a good resolution. In this paper, selection and installation of appropriate sensors for measuring processable material flows and levels are considered. Similarly, actuators to be manipulated need to be carefully specified or selected, if they already exist on-site, to satisfy the process control targets. Examples are given to show their importance in the process control design.

In general, the objective of this paper is to give insight into process control design principles for crushing and screening processes. The target for process control design is to provide with an automation system enabling efficient user operation with high and robust control performance for guaranteing a stable process with increased process through-put, product quality and uptime. To achieve that, several aspects must be considered such as selection of appropriate control strategy and controller types, design of appropriate sensors and manipulatable actuators that can be operated over their whole range. Finally, the paper treats a real industrial case where a crushing and screening process was automated in plant-wide –wise to improve plant operations, capacity and efficiency.

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