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Methods for traceability in continuous processes–Experience from an iron ore refinement process

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Abstract

Every production process is exposed to disturbances leading to production of defective products. The disturbances are seldom immediately discovered, and need to be traced afterwards. Traceability, or the ability to follow a product through the process, is therefore vital since it aids the localisation of the source of the disturbance. Traceability has for a long time been a possibility in part production, but in the continuous process industry it is still problematic. Examples of problems are complex flows, closed systems and large buffers. Hence, the purpose of this paper is to describe methods that can be used to achieve traceability in continuous processes, and give an example of when they may be applied. To identify suitable traceability methods, the literature search was conducted as well as discussions with researchers from the process industry. How the methods work is presented together with their advantages and disadvantages. Furthermore, an example of which traceability methods could be used for achieving traceability in a continuous iron ore refinement process is given. Seeing the diversity of available methods, achieving traceability in continuous processes should be possible.

Keywords: Residence time distribution; Iron ores; Ore mineralogy; RFID

1. Introduction

An announcement of a product recall of about 90,000 locomotive toys was issued in September 2007 by Fisher-Price (US Consumer Product Safety Commission). Product recall announcements like the mentioned one are issued daily by companies around the world and most consumer product stores handle product reclamations daily. This exemplifies that defective products and product deviations are not always identified directly, even if this is desirable. Instead the causes often need to be traced back through the process from customer complaints. The ability to trace a specific product during the process, usually called traceability, is consequently important for identification and elimination of causes of product deviations. Other benefits of traceability are that it minimises the extent of product recalls and ensures lot uniformity in products (Juran and Gryna, 1980). Furthermore, traceability can be used to identify causes of positive changes in product characteristics.

Traceability is common in part production and often easy to achieve, since various kinds of identification markers can be attached to a unit. Moreover, the literature about traceability is dominated by applications in part production. However, creating traceability in continuous processes implies vast challenges: process flows can be parallel, serial and reflux; sub processes can be continuous as well as batch-wise. These challenges imply that other types of traceability methods are needed for creating traceability. To understand more easily how these traceability methods can be applied, the authors consider that an example is appropriate. A suitable continuous process for exemplifying how various methods could be used was found in the iron ore mining industry, and the refinement of iron ore

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to iron ore pellets (the process is described in Section 5). The reason for choosing the iron ore refinement process is that all the special challenges connected to continuous process industries are present in this process. Therefore, the purpose of the article *is to compose and describe different traceability methods that can be used for achieving traceability in continuous processes,* and *to illustrate how a method for traceability may be selected from the characteristics of a process section.* The refinement process of iron ore starts in the mines. However, in this paper only the methods for achieving traceability from the concentrator plants to the final customer are discussed.

2. Research methodology

This article is a result of extensive collaboration between the authors and the Swedish mining company LKAB. This collaboration focused on traceability and traceability methods in continuous processes. As a part of this collaboration, an iterative literature search was conducted aiming at identifying traceability methods. An initial literature search was performed in the databases Compendex, Emerald and ScienceDirect.

Most of the articles found were primarily related to other subject fields than traceability methods in continuous processes. However, from the related articles and discussions among the authors, colleagues and researchers at LKAB, new search strings, such as residence time distribution (RTD), trace elements, mineralogical signature and radio frequency identification (RFID), were identified. The second literature search together with the initial one led to the identification of the traceability methods described in this paper. The identified methods are described in Section 4, and each description includes a brief explanation of advantages, disadvantages, and examples of application. A conclusion from the literature search is that literature on traceability methods in continuous processes is rare and scattered in a diversity of research fields.

3. Theoretical framework

3.1. Traceability

In this paper three terms for traceability with distinguishing aims will be consistently used: traceability, traceability system, and traceability methods.

Traceability is here defined as "the ability to preserve and access the identity and attributes of a physical supply chain's objects" (Töyrylä, 1999, p. 38). Traceability is not binary but continuous and always present at some level. This means that it is possible to differentiate between what year, week, or day a product was manufactured.

Traceability system is defined as the system that enables traceability in a process by combining process information with models of material flow in the production process. According to Steele (1995), Töyrylä (1999) and Jansen-Vullers et al. (2003), there are four elements connected to the design of a lot-tracing system:

1. *Physical lot-integrity* – How large a batch of raw material is and how well the integrity of the batch is maintained will determine the resolution or precision of the traceability system. The resolution of a system is the minimum number of units that cannot be individually separated during the process, and for example emanate from the same delivery batch.
2. *Data collection* – Two types of data are needed: process data that records process information, and lot-tracing data that keeps a record of movement and merging of batches.
3. *Product identification* – The linking of product and process data.
4. *Reporting* – Retrieval of data from the system, the actual use of the system.

The most important element is physical lot-integrity, since it determines the maximal resolution of a traceability system. The physical lot-integrity for a process is affected by three elements: lot mismatching, lot-end-mixing and lot-sequence mixing (Steele, 1995). Lot mismatching occurs when a new batch is created and the size of the batch does not match the original one, for example when numbers of units simultaneously treated in two process steps differ. Lot-end-mixing arises if lots are processed in repetitive or continuous batches and the organisation fails to retain clear separation between batches, for example when products from parallel process steps with different cycle times are merged. Lot-sequence mixing takes place if the traceability system depends on the first-in–first-out principle and the process fails to pursue this principle, for example when all the rework is conducted at the end of a shift. The physical lot-integrity element is also the element that is primarily affected by the differences in continuous production and part production, since batches are usually not present in a continuous process. The traceability systems used for achieving traceability in part production should also be useful for achieving traceability in continuous production, since it is only the methods for creating the models of material flow that differ.

A traceability method, the third term, is defined as a method that can be used for creating models for material flow in process sections. The same traceability method is rarely suitable to use during the process, because of changes in material properties and various operations in process stages. Therefore, suitable traceability methods need to be identified for different process sections, and the material flow, consequently, needs to be modelled stepwise. The traceability methods that are applied in part production processes can seldom be used in continuous processes, due to the mentioned differences.

The relations between the three terms may be described according to the following criteria: models for material flow in process sections are constructed with traceability