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Technical Paper

Quality control planning to prevent excessive scrap production

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ABSTRACT

This paper presents a risk-based approach for quality control planning of complex discrete manufacturing processes, to prevent massive scraps to occur. An analytical model is developed to optimize the quality control plan (QCP) subject to inspection capacity limitation and risk exposure objectives. The problem is then formulated as a constrained capacity allocation problem. A dedicated heuristic that solves a simplified instance of an industrial case study, from semiconductor manufacturing, is presented to provide insights into the applicability and the operational use of the approach and its potential gains in terms of risk exposure reduction. The main advancement resulting from this work is the proposal of a model of quality control allocation and an understandable algorithm to prevent the production of excessive amounts of scrap. The industrial illustration shows a decrease in potential losses by a factor of 3.

1. Introduction

In mass production industries, like semiconductor manufacturing, the concept of massive scraps is of prime importance. Undetected defects could affect thousands, if not millions, of finished or semi-finished products. Tardy detected defects or failures often lead to product recalls, returns or massive scraps, which are nightmare for industrialists and marketing managers [13]. These catastrophic events are not well publicized as they generate losses due to: re-manufacturing costs, logistics costs, systematic shrinking of their market share, and a severe damage to their image. The consequences for customers concerned can also be catastrophic, ranging from product shortage, injury or death (in case of critical components of health care devices like peacemaker for instance) [11]. Almost each major event, like massive scraps or equipment breakdown, have different origins. However, they share a common characteristic: their causes, even known, have not been detected by the control system and the failure whatever its origins, has affected a lot of products before being detected. In case of massive scraps, quality control plan fails its mission.

This paper acts on the planning of quality controls. It helps in the prevention of massive scraps by planning quality controls regarding production control and control resources constraints. Quality and production control plans are intrinsically linked. However the actual design of these plans are separated. This exposes industrialists to major losses. Fig. 1 illustrates this risk using one-month real data coming from a semiconductor fab. The risk exposure, referred in this example, is expressed by the number of products processed since the processing date of the last inspected product. It is called "Material-At-Risk" (MAR). The figure draws the temporal evolution of the MAR of two different processing machines. The two machines presented are equivalent as they are qualified for the same operations. Each point in the curve corresponds to one of the following events: (i) if the point represents an increase of the MAR, the event is the processing of a new product (or a lot) by the considered machine; (ii) if the point represents a decrease of the MAR, the event is the quality control of a product (or a lot) that was processed by the considered machine. A control reduces the MAR of a given value depending on production control, that is the added value of the control regarding risk exposure; (iii) else, the event is similar to that in (ii), but the performed control has no added-value.

In the illustration provided in Fig. 1, the first observation is that the risk exposure is not managed equitably between the two machines. Over the monitored period, the maximum value of MAR reached by Machine2 is 500, while Machine1 has a maximum MAR of 200. The mean values of MAR are 222 for Machine2 and 74 for Machine1. Machine2 is more exposed to risks as its MAR is higher than for Machine1. This could be partially justified by the fact that the second machine is more loaded than the first one. However, there are a significant number of controls on Machine1 without any added value (without reducing the MAR). The gap between the maximum values of MAR implies that inspections are not allocated to minimize, or at least to control, the MAR. For example, one might

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0278-6125/

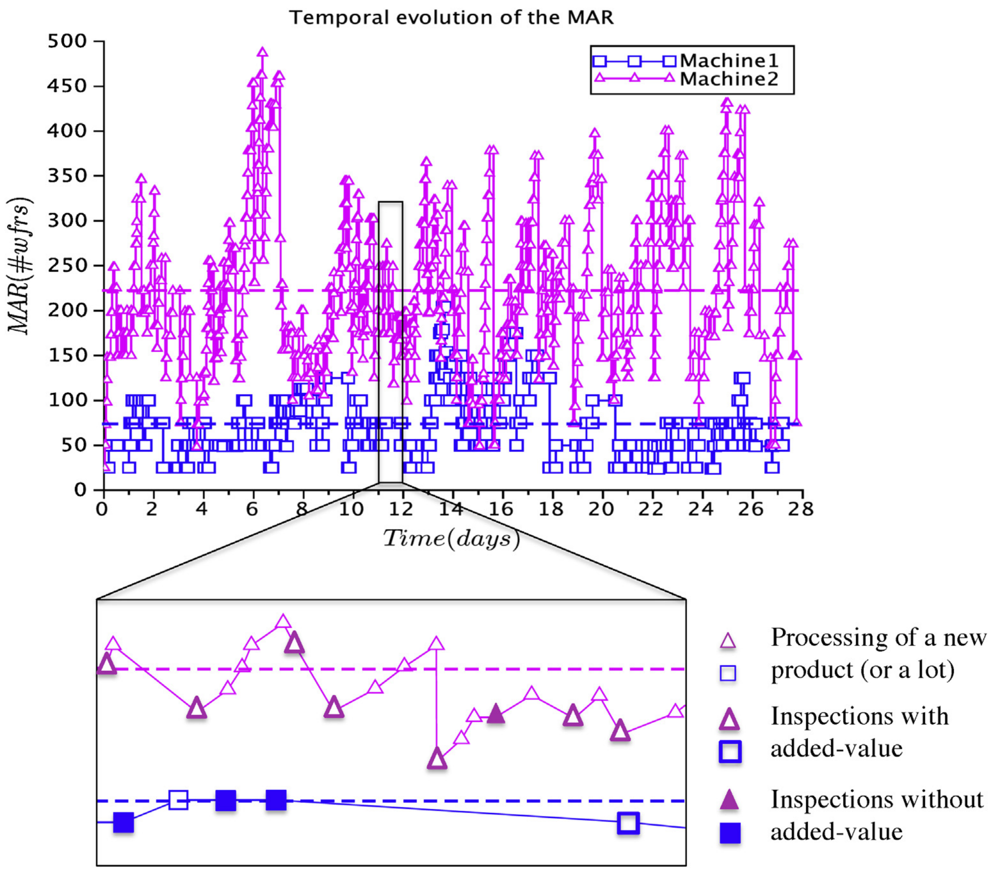

Fig. 1. Illustration of uncontrolled risk exposure.

consider using the control capacity used for controls performed on Machine1 that did not add value, to perform additional controls related to Machine2.

The second observation concerns MAR peaks of a given machine and their significance. Assuming that the control resource is supposed to be error-free, the failure not intermittent and the machines unable to self-repair, each pick corresponds to the maximum number of potentially defective products. A first question arises here: (Q1) If the maximum losses become actual, is the production organization able to face such disturbances ? This unveils two others: (Q2) What is the threshold of actual loss that production organization can face and can absorb in reasonable time? and (Q3) How to take into account this threshold, if any, in the quality control plan?

The purpose of this paper is to tackle this issue by providing quality control planning that takes into account both the production plan and a risk exposure insurance level. This article intends to enhance classical quality control model, focused only on the detection speed, by including consideration of massive scraps prevention. There is then a clear inspection allocation problem, constrained by capacity of controls and influenced by Work-In-Progress (WIP) bubbles and evolutions [10].

The remainder of the paper is organized as follows. Section 2, provides a review of the literature related to process control approaches and methodologies, and how quality controls have already been coupled with operations. The main proposal of this paper is described in Section 3. It details definitions, assumptions and formulates a general model of material at risk management. The forth section is an illustration of how the model of MAR can be adapted and used by testing the approach through a real example of an industrial application. It demonstrates the usefulness of such an approach to mastering risk exposure in complex discrete manufacturing systems. Section 5 discusses the limitations and gives some perspectives of this proposal which constitute the directions for further research. Section 6, which summarizes the aim and the contribution of this research, concludes this paper.

2. Literature review

Quality control crosses various disciplines in an effort to establish appropriate layers of protection [24]. Accordingly, this review focuses on the quality control techniques available to prevent the production of excessive amounts of scraps: risk management, Statistical Process Control (SPC), inspection allocation, and the integration of process control into operational activities.

2.1. Risk management

Almost all semiconductor manufacturers need to provide updated risk analyses about their processes and products, and sometimes their machines, with the objective of assuring their customers of their ability to deliver products on time, and in the quantity and quality required. These analyses concern the operational risks, which have to be determined, evaluated (often using ranking techniques), and mitigated, with follow-up for the best case. These are risks of the occurrence of events that have potentially serious consequences. FMECA (Failure Mode, Effects and Criticality Analysis) is one of the techniques most often applied [30], however there are many others. A general survey of modern risk management methodologies can be found in Ref. [28].

In risk analysis, layers of protection are explicitly mentioned. In FMECA, they are listed in the column labelled “Detectability”. However, very few methods link efficiently risk analyses and actual control plan strategies, which would take into account the potential excessive amount of scrap production. From the risk analysis