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Risk Assessment of Non-Repetitive Production Processes

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Abstract

The purpose of this paper is to support the process of production batch size definition in non-repetitive production like MTO or ETO based on reliability assessment. Although theory supposes the production batch size to be equal to customer order, situation observed in real production systems is different. Production often protects itself against manufacturing process unreliability resulting in non-conformed parts with overproduction. To manage the production wisely, the process risk should be evaluated. High ratio of setup costs to unit production costs should be taken into consideration as well as potential risk of each operation. This paper describes a proposed way, coming from the idea of FMEA methodology, to assess the risk and calculate costs related to process unreliability. The result then supports the batch size definition.

Keywords: production; process; MTO; FMEA; costs; reliability; batch

1. Introduction

Managing production processes is never easy. The problem is even more complicated in non-repetitive production like MTO or ETO. [4] Make-to-Order production starts with placed customer order not by some forecasted demand. [5]

In the field of production control we can see very often differences between theory and practice. One of the discrepancies was observed in defining the size of production batch. According to theory the production batch (in non-repetitive production) is equal to the number of pieces ordered by customer. [3,8] It is also the basic principal of pull system (or kanban principal). This is obvious, because in make to order production we are not able to sell potentially remaining products to any other customers. The parts are usually produced for a specific application. But in practice it is not unusual to see a few more parts to be released in production comparing to original customer

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order. Of course this is not a lean approach, but before refusing such behaviour, the root cause was searched and analysed.

2. Analysis of the root cause

Causal analysis was performed to find the root cause. By observing the production processes and interviewing production supervisors responsible for setting the batch sizes, the unreliability of production processes was found out as the main reason. Better utilization of remaining material (analyzed production system uses metal sheets as blanks) was mentioned as a secondary reason. Supervisors suppose the order to be repeated in the future.

Ed.: Production process reliability has two characteristics – quality and time. [10] In this study we are concentrated on the quality aspect – production of non-conformed parts.

Supervisors are always concerned about producing non-conforming parts during any of the production steps. Therefore they protect themselves by increasing number of parts within a batch to have a compensation for it. We can call this overproduction, the worst type of the well-known 7 wastes [6,7]. Although we should aim to reduce it, it is sometimes not so easy, because in MTO or ETO production the products are unique and we are not able to specify the correct setup conditions.

A non-conforming part in non-repetitive production does not represent just production costs of the single part. If there is a need to produce the part again (substitution for a non-conformed one), the production process must be repeated from the beginning to the step, where problem occurred. This means mainly repeating all the setups (usually the most expensive and time-consuming part of the non-repetitive production), stopping production of the order until the substitute part will go through the production system to the actual step and re-planning. Thus the production costs might increase significantly, and extended batch seems to be a possible solution. The task is to set the rule or methodology to be able to decide, whether it is better to produce only the number of parts requested by customer, or to increase the batch size to cover the potential risk.

3. Assessing the risk

For evaluating potential problems (and its effects) connected with a product or process there is a popular tool called FMEA (Failure Mode and Effect Analysis). FMEA is a specific methodology to evaluate a system, design, process, or service for possible ways in which failure (problems, errors, risks, concerns) can occur. [1] It is a methodology good for analyzing potential reliability problems as early in the development cycle as late when a process is already started. [9]

We took FMEA as a way to assess the risk and calculate potential additional costs although the original target of the method is different. FMEA wants to find out the potential problems and take the actions to minimize the risk. In our case we just need to assess the potential problem – risk of producing non-conformed part and then calculate potential additional costs related to re-production of the substitute part.

FMEA uses three basic criteria to assess the problem [2]:

- Severity
- Occurrence
- Detection

The result (RPN - Risk Priority Number) is obtained by multiplying the values of these three parameters. For our purposes we have made a modification. To simplify the problem, we assume that a non-conformed part will be detected directly when the current operation is finished – before moving to the next production step. Like that the parameter – detection, does not need to be set. So only the two basic parameters of risk: severity and probability of its occurrence (as stated in [12]) are taken into consideration.

Modifications of the traditional FMEA method are nothing unusual. It is obvious that many investigators proposed a modified FMEA approach to overcome the shortcomings of the traditional FMEA by combining fuzzy sets with different techniques. [11] In this case the modification does not come from the shortages of the method, but from a need for simplification.

Anyway the severity and occurrence need to be defined. Let's start with the occurrence. Observations and interviews show that there are different basic factors influencing the probability. A "risk structure" related to each separate production step was defined according to this finding.

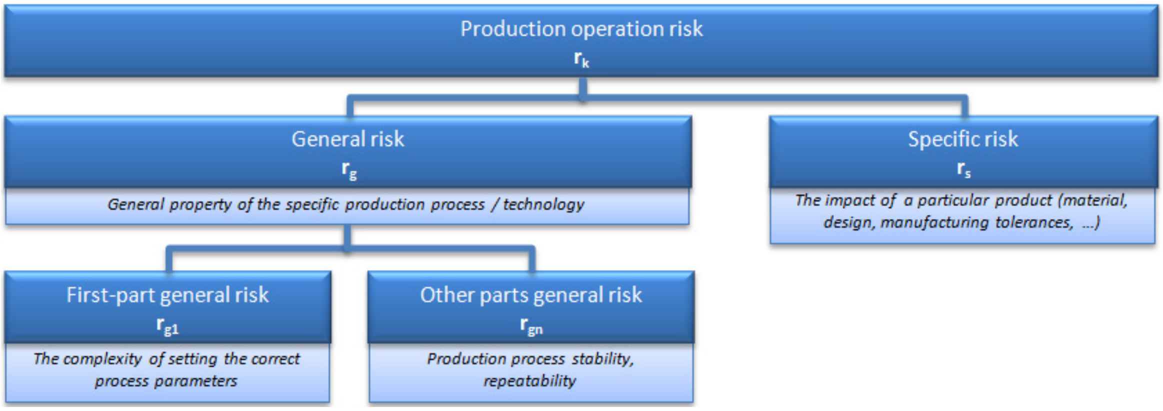

Fig. 1. Production operation risk structure.

The production operation risk represents probability of producing non-conformed part. It considers the process and also the design of the specific product. The process risk (general) comes from the nature of the technology, complexity of machine setup, level of automation, maintenance, age of the machines, etc. But general risk must be then corrected by risk of the particular product, which can e.g. require a specific operation, problematic or new material not used before. Here is the proposed formula for calculating risk of one production operation (*k*):

$$r_k = r_g \times r_s = [r_{g1} + r_{gn} \times (m-1)] \times r_s \qquad (1)$$

r_k	-	total risk of the operation *k*
r_{g1}	-	first part general risk
r_{gn}	-	other parts general risk
m	-	number of parts to be produced (according to customer order)
r_s	-	specific risk related to the particular product

Values of the parameters should be defined by the process engineers. General risk parameters for each technology / workstation are defined at the beginning according to historical data. So each time it is necessary to determine just the specific risk coming from product design.

The last parameter - severity - in this case means that a substitute part needs to be produced from the first operation to the actual step. It represents additional material costs, repeating setups on all previous workstations and unit production costs. We focused mainly on calculating the setup + production costs. Of course, the amount of costs depends on the step of production process, where the problem occurs. For cost calculation we should consider two possible situations:

- non-conformed part is produced during the first production process step (k=1):

$$c_1 = c_{u_1} \times r_1 \qquad (2)$$

- non-conformed part is produced during any other production step (k≠1):

$$c_k = \sum_{i=1}^{k} \left[(C_{pf_i} \times d) + (c_{u_i} \times r_k) \right] \tag{3}$$

c_1	-	manufacturing costs for repeating first production process step
c_{u1}	-	unit costs for the first production process step
r_1	-	first operation risk
c_k	-	manufacturing costs for repeating production process from the first to the actual step *k*
C_{pfi}	-	cost for preparation and finishing the batch production – setup costs
d	-	variable for correction of risk
c_{ui}	-	unit costs for production process step *i*
r_k	-	total risk of the operation *k*

Ed.: material costs are not included in this calculation

Variable d is used for limiting the risk r_k in the formula. If there is a need to repeat the process (produce a substitute part), we consider the setup costs to appear maximum once even if r_k value is higher than one, therefore:

$$r_k < 1 \ \rightarrow d = r_k$$
$$r_k \geq 1 \ \rightarrow d = 1$$

Total production costs coming from the risk - C_T (without material costs) are a sum of particular manufacturing costs per each operation:

$$C_T = \sum_{k=1}^{p} c_k \tag{4}$$

4. Cost comparison

With this methodology we can decide whether it is better to produce just the ordered number of parts, or intentionally increase the production batch size to cover the possibility of manufacturing a non-conformed part. The main influencing factors to be considered are material costs and costs coming from the production process risk, where we discuss the probability of non-conformed part manufacturing at each production step and setup costs.

Alternative 1: To produce just the number of parts required by customer. The costs will consist of:

- Production costs of producing customer required number of parts
- Additional costs coming from the process risk (C_T) – potential re-production of substitute parts (without material costs)
- Unit material costs multiplied by the sum of each production process step risk – material costs for potential re-production of substitute parts

Alternative 2: To produce increased batch to cover potential risk. The costs will consist of:

- Production costs for increased number of parts (material costs included)

Results of these two variants should be then compared to support the final decision.

5. Conclusion

Observing the real production systems dealing with MTO or ETO production the discrepancy between theory and practice was revealed. Although number of pieces released in production should be theoretically equal to customer order, the real production batches were in some cases increased above the requirement. The purpose of this study was to analyze the situation, find out the root cause of the discrepancy and propose a methodology to set the economical batch size for non-repetitive production.

Production process unreliability was revealed as a main reason for increasing the batch size. Production supervisors want to protect themselves against cases, when non-conformed parts are produced during the process causing the need of re-production of the missing parts (additional costs). Therefore some substitute parts are produced from the beginning of the process. Although this is not a lean approach, in some cases this could reduce the manufacturing costs.

However, subjective feelings should be replaced by a reliable risk and cost analysis. For process risk assessment the modified FMEA methodology was used. Instead of the original idea of the method - assessing the risk and looking for actions to minimize it, the proposed methodology just assesses the risk, and then calculates potential costs coming from the process unreliability. If setup costs and identified process unreliability are high, while the unit costs are low, it is very likely that increased number of produced parts compared to customer order could decrease the total costs at the end. Of course in cases of low setup costs and high process reliability there is no sense to produce more than customer requires.

The basic output of the study is the methodology to define the economical batch size in job production based on process reliability assessment and cost calculation. Production process reliability, setup and unit costs were identified as the main factors influencing the batch definition. Of course material costs and its utilization should be taken into consideration also. For supporting the assessment of the occurrence parameter a risk structure for the single production operation was proposed. Further activities should be concentrated on evaluating the methodology in practice and searching for simple and quick way to assess the risk coming from the product design or manufacturing process applicable in small companies.

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