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Procedia Engineering 182 (2017) 387 – 395

Procedia Engineering

www.elsevier.com/locate/procedia

7th International Conference on Engineering, Project, and Production Management

Issues of Measuring the Course of Batch Production Processes

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Abstract

In order to meet demands induced by development of manufacturing processes and production systems, new criteria and indicators that would allow a multiple aspect and realistic rating of batch production process courses are necessary. The objective of this paper is to present the correlation between production processes measurement, its rating and production control, basing on case study analysis from production enterprise. A new instrument for production control – a multicriteria rating of the batch process method, which utilizes seven criterions, was designed. In the future, indicators for all seven criteria, standardization formulas and a computer program will be developed.

Peer-review under responsibility of the organizing committee of EPPM2016

Keywords: batch production; multicriteria measurement; feedback; control system; batch process

1. Introduction

Along with the development of manufacturing processes and production systems appears a growing need to improve the means to control these processes. With time, in case of complex and expensive production systems, simple production control methods proved insufficient. The production process, beside producing products, yields information which could be used for improvement of the process itself – in case of batch production, due to lack of literature and theoretical or practical solutions, personnel responsible for production control do not posses means necessary to not only apply, but even gather this information. Therefore knowledge that could be used to advance quality of entire process is wasted. It became necessary to develop new criteria and indicators for evaluation of processes course, in order to provide companies management and production management with essential data required to maintain production control and use the potential of information derived from production process. Speaking of new

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Peer-review under responsibility of the organizing committee of EPPM2016
doi:10.1016/j.proeng.2017.03.119

indicators, it is imperative not only to include new means of measurement of some aspects of production processes, but also to gain new view over their present rating system itself, expanding it with new criterions of rating. Therefore while analyzing the course of batch production processes, its rating should not be focused on technological criterion alone, but on market, economical, social and ecological criterions as well [1, 2]. In addition, management of batch production implies many difficulties which result from characteristics of process itself, such as variability of supplies on production posts, variable load of production posts or frequent rearming. Therefore it is important not only to develop measurement criterions and corresponding indicators, but to adjust it to characteristics of batch production. It is important to remember that the effect of batch process is not measured only by its final product, but by level of satisfaction of various stakeholders, such as clients or workers as well.

2. Characteristics of batch production process

According to definition introduced by professor Durlik [2] process is defined as orderly series of actions, in result of which the consumer (user) receives a product. This definition is commonly known and quoted by many authors [4]. According to Brzeziński [1] production process is defined as entirety of actions, leading to creation of final product of defined value from raw material or materials.

Two forms of production organization can be distinguished [1, 4, 9]:

- batch production process
- line production process.

Batch processes present no (or very slight) repetitiveness of actions on specific work centers, which leads to high frequency of rearming. Characteristic features of batch processes are [17–19]:

- low level of instrumentation
- high, but variable reserve of production in progress
- technological production structure (most common)
- production planning depends on orders
- live distribution of load amongst the production posts.

If the production occurs without constant rhythm, and work centers have to perform various operations which course through time is not regulated by cyclic, repetitive over time schedules, the whole operation lacks permanent relationships between work centers and operations, and control system often works under circumstances of "information gap" in regard of data such as: duration of production cycle, duration standards, machines and human load. This leads to question: how to control such process, how to verify and improve it. These questions became even more important nowadays, as batch production became very common form of production, since it provides equilibrium between stationary and line production [3, 5].

3. Control system of batch production process

Speaking of control over batch production processes, two definitions should be established. First definition concerns control over production flow. It includes the influence of actions from near future on final products' sales plan. It's connected to production schedule of products, subassemblies and material requisition. The second definition is production control. This definition is superior, since it represents more complex approach. Production control is function of control and regulation of material flow, including entire production process – from the moment when resources demand is defined, until the provision of final product [1, 8].

Design of control system requires definition of following elements [7]:

- control information – data used for process control, for example control over parameters such as supply level of work in progress; balance of production potential; time advancement, which allows to define beginning of the production of elements batch

- control model – control algorithm, which would define the type of action performed when Control Information is introduced to the system. In case of complex algorithm, it is possible to define main control operations, for which more detailed algorithms can be designed
- information system – it defines content of input and output information, as well as frequency of their upload
- control tools – in other words technical means necessary to acquire and process information, in most cases computer hardware and software
- organization structure of control center – also known as regulator or controlling object, creation of such structure is imperative, since decisions over production control are made on many different levels of management structure, therefore it is necessary to define responsible units along with information provided to them.

Control system should be subjected to rating, which could include following criterions [7]:

- sensitivity – systems ability to react on changes that occur in ratio of real time production flow to flow corrected by control information
- reaction speed – length of time from acquisition of control information to the moment of their upload into control center
- control elasticity – feature regarding ability to shift control parameters
- compatibility of system functionality with users demands.

Basic targets of production control are [10, 11]:

- completion of main schedule of production
- completion of material demand schedule
- maintaining production potential load and it is regularity on proper level, as well as their proper utilization
- maintaining proper level of work in progress supply
- achieving complex level of service realization
- achieving increase in productivity and quality of production.

Important element of batch processes control is definition of feedback. This definition has been used since approximately 1970 in cybernetics and it is a combination of management system elements, it means a connection between output of an element and input of an element of the same type [14–16].

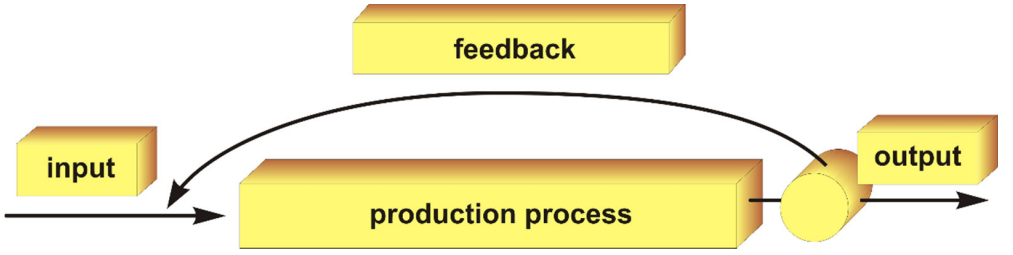

Fig. 1. Feedback in production process control scheme.
Source: [14–16].

Fig. 1 presents that in order to finish production process it is necessary to provide it with certain material and non-material goods, such as resources, basic products, energy, information, finances or knowledge. These goods form set of input elements for production process. Output is formed by elements such as final products, waste or information. In the meantime, after process is complete, feedback occurs, which provides information about process course. This data helps to improve processes' work organization.

4. Needs and information channels in batch process control

In order to control production it is necessary to define the information flow. The following questions need to be answered:

- What type of information is needed?
- Where can they be acquired?
- How to gather information?
- How to process information?
- To whom should it be passed on?
- In what form should it be passed on?

According to production controls' target, it is necessary to gather information used to evaluate realization of main production schedule and material demand schedule. In addition it is necessary to acquire data regarding:

- level of production potency load
- level of supply of work in progress
- data connected to product quality.

The information would derive from whole spectrum of production sections, from management, who possess knowledge about production schedules, to common workers well acquainted with production machines load. Additionally, data acquired from customer service would be needed in order to evaluate product quality from customers' point of view. Warehouse workers would provide data about supplies.

Gathering of information regarding production control should be constant, continuous process; therefore it is desirable to utilize computer software in order to gain live transmission of data regarding current load levels, supplies as well as production achievements and status. Gathered data should be formed into report and delivered to company's management, and in form of abstract reports – to specific sections. Fig. 2 presents simplified information flow in production control.

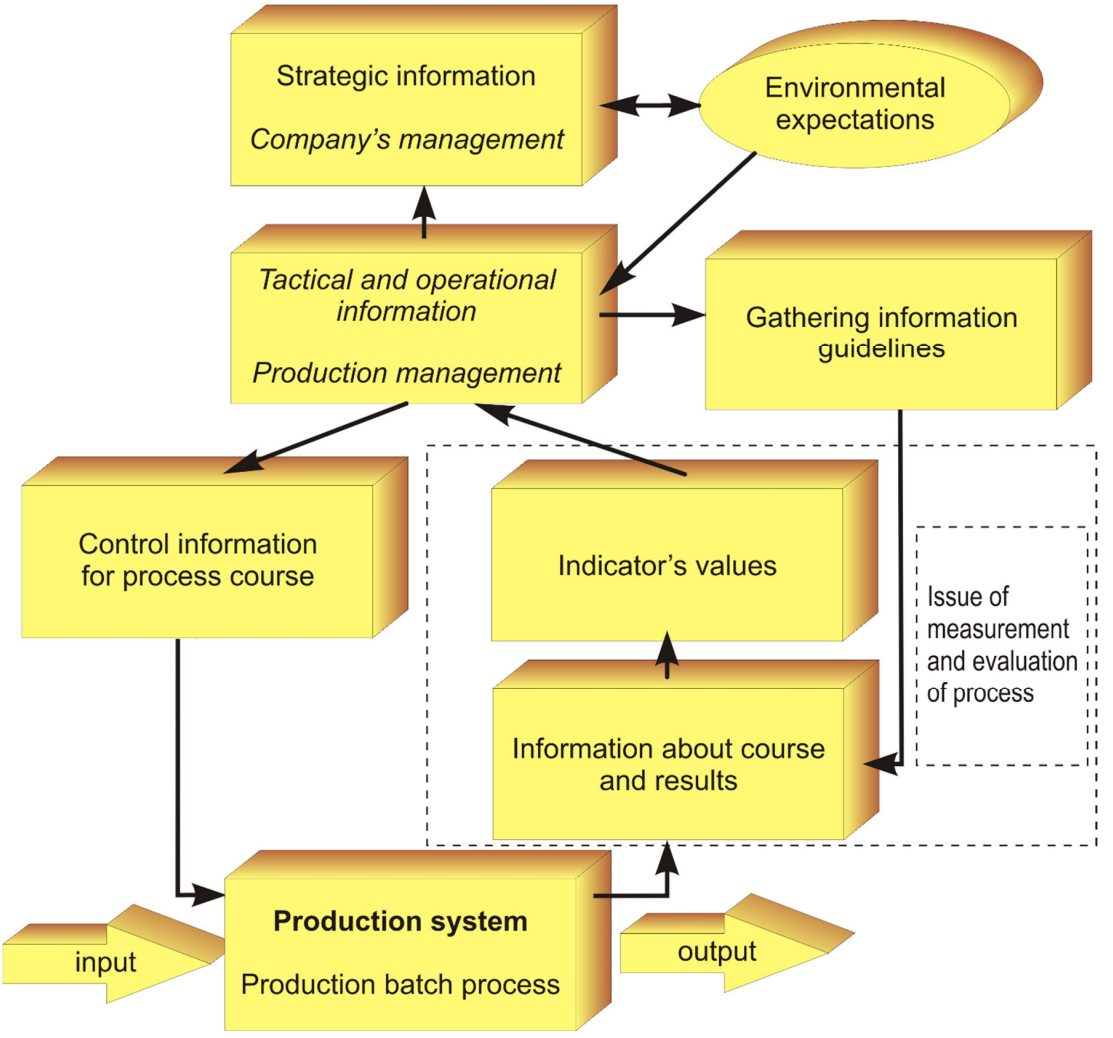

Fig. 2. Schematics of information circuit in process course control system.
Source: Authors elaboration based on [14–16].

Fig. 2 presents development of production control feedback schematics. The feedback information from Fig. 1 was presented as course of information about process results, and afterwards as values of chosen indicators delivered to production management. Basing on these information, as well as on strategic information received from companies' management, production management develops control information for process course and sends it again to production system. From analysis of Fig. 2 it can be concluded that environmental expectations (both close and distant) have high impact on management decisions. Following information can be distinguished:

- competition – their products, prices, general sales politics, complaints
- providers – their wares, quality and prices of wares, time of order realization
- clients – their needs in the field of products specification as well as expectations in regard of companies' politics
- political/regulations environment – its influence on companies' work.

Additionally the information flow from management to its environment should be distinguished, since there is possibility that company induces influence on its surroundings. For example it is possible to create demand, lead aggressive price politics in order to weaken competition, build relationship with suppliers. This part of scheme constitutes the feedback between company and its environment.

Another information channel is the one between companies' management and production management. Companies' management sends information regarding strategic decisions, general direction of development and ideas for new products, while production management feeds data directly regarding production systems, production limits, time required for production of single final product, production load, requirement for new equipment and need for employment of additional workers.

The production management specifies general guidelines for gathering information needed for process analysis, which allows for further evaluation of its course. These guidelines answer following questions:

- What type of information is needed for process evaluation?
- How to collect information – continuously or periodically?
- Does equipment needed for data gathering exist, and if so – how to obtain and implement such equipment, if not – is it possible to create it?
- How to analyze and interpret data?

The guidelines above can help in obtaining data which allows designating production process rating indicator. This indicator can be created by management or one that already exists can be used.

With the result of production process rating the production management can prepare production control information, such as:

- production schedule
- process flow diagram
- size of production batch
- essential resources.

These information can be used to control each production process separately as well as entire production systems. Increase in production of one product can lead to decrease in production of other products, or severely influence their production processes, forcing delays or additional rearming. Additionally, information obtained directly from production process will influence process rating gauge.

Important fact is that on the scheme presented in Fig. 2 there is no beginning for the information flow. Data received from environment must be confronted with information about existing production system. Fig. 2 has marked fragments related to issue of process measurement, which is the field of further analysis.

5. Case study: research in X Company

In order to empirically verify means of measurement of batch production processes, as well as the flow of control information for the production, research in production company was undertaken. The case study was conducted on several work stations. It included one month of participating observation, 2 weeks of non-participating observation, historical data analysis and surveys.

The "X" Company is focused on manufacturing hydraulic power supplies, valve blocks, environmental protection equipment, ship equipment, car winches, technical vehicles and more, as well as accomplishing individual orders. Diverse working profile and production on demand for both national and foreign customers requires smooth management over available resources, amongst which most crucial are specialized production machines such as milling machine, lathe or bending machine and highly qualified personnel. Processes performed within the company usually concern from one to a couple product pieces and prototype production. As a result of small production batch and sudden additional orders, which often occur while producing prototypes, it requires frequent rearming.

Product manufacturing is performed using batch production, as a result of high variability of production processes depending on type of product, variable durations, variable demand on production resources and varied order of

operations. On account of that, it is essential to correctly distribute load upon specific work centers and plan the flow between them. The word "flow" in this case applies both to products flow, as well as flow of information about its current location relatively to entire production process [13].

6. Issue of measurement and evaluation of course of batch production process in "X" Company

Increasing amount of orders as well as producing new products forced introduction of change in production control methods and in production processes themselves. This type of changes often allows increasing productivity without new investments.

It is suggested to divide measurements and evaluation of processes into 5 criterions: economical, ecological, social, market and technological [12]. The market criterion is about evaluation if the product meets client's individual needs and if the prices and duration of time from the products' order to its delivery to the client are elastic. It is about evaluation of product based on clients' point of view. Social criterion concerns working conditions, requirements on personnel qualifications, satisfaction from work - rated for example with a survey, or by measuring absence at work. Ecological criterion is about means of natural environment protection, utilization and segregation of wastes and usage of various media. This criterion is about social responsibility of companies.

Due to restrictions imposed by company "X" it was possible to completely evaluate technological criterion alone, while other criterions were only evaluated briefly. After completion of research it was decided that multi-criterion process rating required further modifications in order to include two additional criterions. Planning criterion is related to fulfilling general production schedules, which is one of the main targets of production control. Second additional criterion, which is general evaluation of company, allows evaluating companies' state not only by measuring fulfilled production processes, but by its general condition as well. Fig. 3 presents modified structure of multi-criterion process rating.

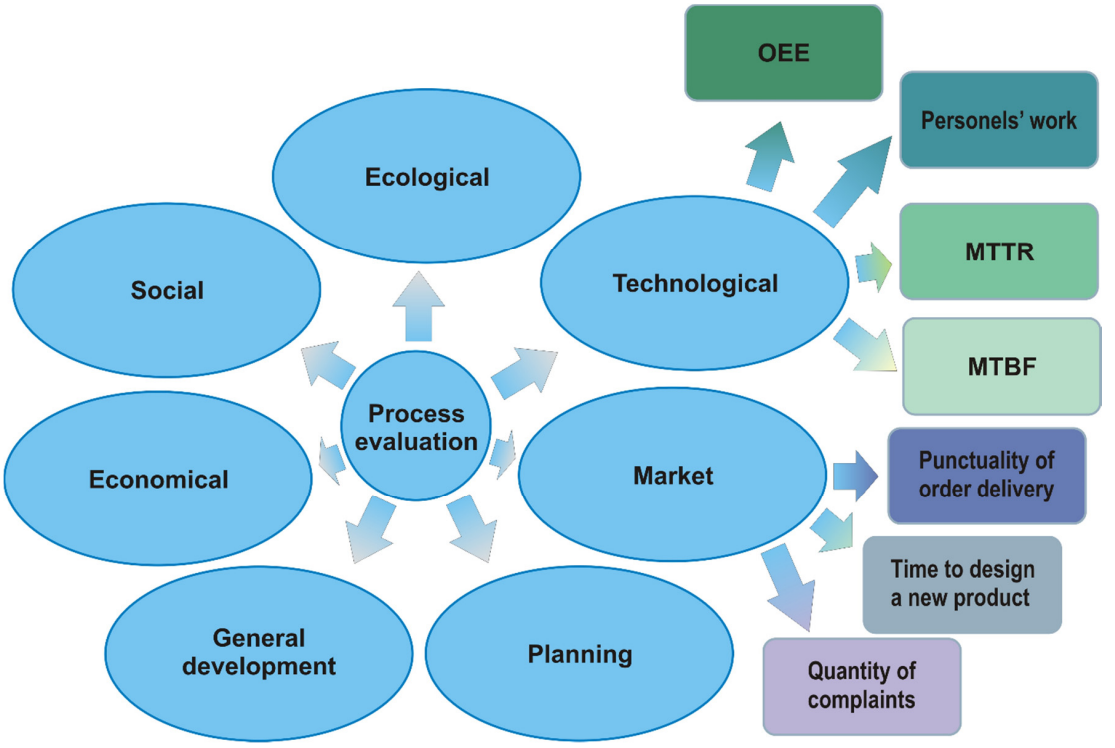

Fig. 3. Multi-criterion batch production process course rating measurer.

After introducing described modifications into the multi-criterion measurement ratio, researchers intend to perform further measurements in "X" company. Amongst all the processes, ones that yield highest quantity of products and those which produce products for key customers would be subjected to the modified analysis. They would be evaluated based on the above criterions, and in case they do not meet the expectations, improvements would be designed. This type of analysis would need to include one more measurement aspect – in batch production process each work center can produce components for a couple final products simultaneously. This leads to some difficulties in use of basic indicators, such as mean time to repair (MTTR) and mean time before failure (MTBF), [6]. During line production, in case of single failure among the production chain, whole process ceases, which allows easily measuring time of delay and using it to decrease the MTBF ratio. In batch production it proves difficult to strictly follow the process itself, because although the components pass from one production post to another in strict order, the moment of their transfer is unpredictable or difficult to predict – it depends on present load of the work centers and on workers' other duties. In the company "X", when one of hand lathes experienced failure, second machine could take over its work, and since at current moment the load on both work centers was low, it allowed to carry on the process without any delays in production of other products. If the MTBF indicator would have been measured at that moment, it should have been decreased on account of failure – but it would have been hard to determine the value of decrease. This is why while using these indicators in batch production analysis; they should be designated for machine work over certain period of time. On the other hand it would mean that the indicator would measure the machines' capability for all the processes that pass through the machine during this period of time, not only for the specific process that is subject of the analysis. This leads to a question if the evaluation should be performed for specific processes or the work centers alone. However while in case of technological evaluation it would provide the management with information about work of individual work centers, and can be used for production flow control, market and economical criterions must be applied to specific process, since the first criterion evaluates adaptation of product to clients expectations, and the latter evaluates ratio of acquired effects to carried expenses. It is necessary to define this value for specific process, otherwise the result would not provide any useful information for the management.

7. Conclusion

When analysis of process is carried out using many criterions and indicators, as a result we receive complex rating and evaluation. It should be remembered that the effect of production process must be measured not only by the final product supplied to warehouse, but with level of satisfaction of clients, workers and other stakeholders as well. Moreover, effect can be measured by ratio of acquired income to expenses, or even by evaluation of entire company on account of social responsibility. However the main target of evaluation of process course is to collect data. Any information obtained during evaluation should be processed into reports, and then distributed to specific workers, who would apply the results in practice. If obtained data would not be processed and used by workers, entire evaluation would be a waste of time and resources.

Since nowadays computers are used in almost every field, creation of software which would allow gathering, distribution and analysis of data should be considered. Researchers decided it is imperative to prepare set of guidelines for creation of such software. This software would be divided into data gathering modules, each for every criterion. Within these modules workers from specific sections would introduce information unique for their field of work. For example workers from customer service would provide data regarding complaints for market criterion; accountants would provide data regarding costs and expenses for economical criterion. Data for social analysis would be provided by Health and SafetyInspector in form of audit, ecological criterion would be analyzed in form of audit as well. Technological criterion would be measured both by workers, who for example would provide data about machine failures, and with data supplied directly to the system. Researchers are planning to assign barcode for each component, by scanning these codes the information regarding duration of specific operations would be fed directly to computer.

Acknowledgements

Ministry of Science and Higher Education
Republic of Poland

7th International Conference on Engineering, Project, and Production Management (EPPM2016) was financed in the framework of the contract no. 712/P-DUN/2016 by the Ministry of Science and Higher Education from the funds earmarked for the public understanding of science initiatives.

7th International Conference on Engineering, Project, and Production Management (EPPM2016) finansowana w ramach umowy 712/P-DUN/2016 ze środków Ministra Nauki i Szkolnictwa Wyższego przeznaczonych na działalność upowszechniającą naukę.

7th International Conference on Engineering, Project, and Production Management (EPPM2016) was co-organised by the Agency for Restructuring and Modernisation of Agriculture (Poland).

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