Advances in Manufacturing Technology XXVII

Cranfield UNIVERSITY

Proceedings of the 11th International Conference on Manufacturing Research

Incorporating the 28th National Conference on Manufacturing Research

Essam Shehab. Peter Ball. Benny Tjahjono
Editors

Cranfield UNIVERSITY

Advances in Manufacturing Technology XXVII

Proceedings of the 11th International Conference on Manufacturing Research

Incorporating the 28th National Conference on Manufacturing Research

Essam Shehab, Peter Ball, Benny Tjahjono
Editors

Editors

Dr Essam Shehab, Dr Peter Ball and Dr Benny Tjahjono

Cranfield University
Cranfield
Bedfordshire
MK43 0AL
UK

ISBN 978-1-907413-23-0 ISSN 2053-3373 Cranfield University Press

11th International Conference on Manufacturing Research

19th - 20th September 2013

Organised by
Cranfield University

Organising Committee

Conference Chairmen
E. Shehab, Cranfield University
P. Ball, Cranfield University

Programme Chair
B. Tjahjono, Cranfield University

Conference Secretariat
E. Collins, Cranfield University

Local Organising Committee
K. Salonitis, Cranfield University
I. Sanya, Cranfield University
T. Bandee, Cranfield University
S. Fletcher, Cranfield University

COMEH Advisory Committee
L. Newnes (Chair), University of Bath
K. Case (Deputy Chair), Loughborough University
D. Stockton, De Montfort University
D. Mynors, University of Sussex
J. Gao, Greenwich University
M. Saadat, Birmingham University
Y. Qin, Strathclyde University

International Scientific Committee
A. Al-Ashaab, Cranfield University
H. Abdalla, University of East London
P. Ball, Cranfield University
T. Baines, Aston University
C. Beadle, Rolls-Royce
K. Case, Loughborough University
K. Cheng, Brunel University
B. Clegg, Aston University
S. Evans, Cambridge University
C. Fowler, Airbus
J. Gao, Greenwich University
M. Halliwell, Rolls-Royce
D. Harrison, Glasgow Caledonian University
R. Hole, Airbus
G. Huang, University of Hong Kong
M. Karamanoglu, Middlesex University
A. Long, University of Nottingham
J. Lee, University of Cincinnati
P. Maropoulos, University of Bath
C. McMahon, University of Bristol
D. Mynors, University of Sussex
S. Newman, University of Bath
L. Newnes, University of Bath
M. Price, Queen's University Belfast
R. Roy, Cranfield University
Y. Qin, Strathclyde University
S. Saad, Sheffield Hallam University
M. Saadat, Birmingham University
M. Shafik, University of Derby
E. Shehab, Cranfield University
P. Shore, Cranfield University
D. Su, Nottingham Trent University
V. Taratoukhine, SAP
A. Tiwari, Cranfield University
B. Tjahjono, Cranfield University
R. Valerdi, University of Arizona
D. Williams, Loughborough University
N. Woodfine, Southampton Solent University
Y. Yan, University of Kent

CONFIGURATION OF ROBUST MANUFACTURING SYSTEMS

Matthias Heinicke
Institute of Ergonomics, Manufacturing Systems and Automation
Otto von Guericke University
Magdeburg
Universitätsplatz 2, 39106 Magdeburg, Germany
matthias.heinicke@ovgu.de

ABSTRACT

Considering the increasing turbulence in the markets, many companies are faced with the task of responding to changes in customer demand in a flexible and timely manner. A variety of current research projects in terms of configuration of production systems deals with the increasing flexibility of several elements of a production system or the entire system, to meet the need for flexible responses. Furthermore, there is the avoidance or reduction of any kind of waste, including the creation of standards for the information and material flow processes at the heart of the company's efforts. Against this background, also organisationally robust processes are increasingly becoming the focus of operational actors. This paper points out the possibilities of influencing production systems and what characteristics exist regarding the requirement of structural changes. In this context, production control by defined loops and checking structural performance are indicators relevant to the focus of following considerations.

Keywords: robust manufacturing system, exertion of influence on manufacturing systems, manufacturing control.

1 INTRODUCTION

For several years, the trend towards increased flexibility and changeability of specific elements of factory operation can be observed. Despite the different tendencies in the modern study of production systems in terms of efficiency and adaptability allows the fundamental objectives for the production summarised as follows. It will be exclusively manufactured goods that the customer pays for. Accordingly, a customer focus within modern production systems is required. In addition, the production can be realised in the form of robust processes. In this context, it is aimed at avoiding or reduction of disorganisation. This contribution conducts an approach providing a framework for action, as the operational users recognise the need for intervention and take appropriate measures in this regard.

2 ROBUSTNESS IN THE ORGANISATIONAL CONTEXT

In this context, various influencing factors work on an existing production system. Accordingly, their impact is currently represented mainly by the effort of increased changeability. This adaptability includes an increased responsiveness to changing environmental conditions (customer demand, pricing pressures, supplier development) starting from a certain flexibility within the basic underlying structure of production. Consequently, flexibility and adaptability always contain a reactive or proactive anticipation and adaptation to the turbulence of the environment.

The focus of this paper is the optimisation of the transformation process and the avoidance of operational and organisational errors. This implies improving the process capability, increasing process linking and an increased process reliability (see Section 5.2) in terms of organisationally robust processes. Operational and organisational robustness expresses the ability of a system obtaining his functionality even under fluctuating environmental conditions. Hence, this contribution intends in particular the interaction between external environmental conditions as well as technical and organisational aspects of production systems in the context of ensuring a reliable operation of organisational processes using a hierarchical model to analyse.

3 ASPECTS OF PRODUCTION SYSTEM DESIGN

3.1 Approaches in Planning and Design

There are two basic approaches to design and plan production systems. The classic factory planning approach enables a renewal of production systems by structural change or redesign. In this case, an analytical derivation of design criteria for the layout and overall factory is conducted by the systematic study of equipment requirements, staff, process structure, logistics requirements and dynamics of area use (Bergholz 2005 and Dombrowksi, Hennersdorf and Palluk 2007). This corresponds to a majority of a renewal process in a top-down approach. Due to the lack of basic data, using factory planning methods and routines only allows to find reliable and appropriate solutions not exceeding the workplace level. Moreover, volatile environment conditions and changing requirements cause that the remaining potential cannot be exploited using this deterministic approach.

Against this background, in recent years the staff-oriented concept of lean manufacturing was gaining attention. The bottom-up approach involves the development of improvements to the layout and in particular at the level of workplace design in a participatory process. Hence, this represents an ongoing process improvement during production on the basis of an existing layout and operational organisation, without undergoing structural or organisational changes. This approach aims at extracting knowledge and experience of the employees to develop potential improvements at the workplace level.

During implementation of technical and organisational production systems arise improvements due to changing product characteristics and / or their amount (production programme) initially at the workplace level, which in turn can be exploited superficially through employee-oriented approaches such as lean management. After implementation there are unforeseeable constraints (such as qualification requirements) and changes in the product (customer demand in type and quantity) and of technological processes (new technology). Thus, adaptation needs of the production system emerge regarding organisational structure and operational organisation, investment, technical-technological aspects and personnel.

Based on incremental and continuous improvement steps, thus an adjustment of various elements of the production system at the workplace level occurs. This procedure permits an adaptation of various potential improvements through the adsorption of employee experiences (Schuh et al. 2007). On the contrary, there is the risk of path dependency (Cordes and Hülsmann 2013). In this context, the starting point for any improvements of a production system is the existing one. Consequently, there is a list of possible optimisation solutions depending of the initial situation. This creates self-reinforcing effects which in terms of improving trends can eventually lead to a dead end situation. Hence, this highlights the need for some flexibility within the search for solutions. Otherwise also the continuous improvement process has reached its limits over time and enables only a pseudo-optimisation within a limited space of action. This puts emphasis to the exigency of detecting the appropriate moment of structural changes.

3.2 Production Control as a Control Loop

In consideration of the planning of the production programme, quantitative planning, scheduling, and capacity levelling seen as elements of the PPC system, the results of the respective upstream planning level represent the input data for the next item. This is called cascaded loops (Nyhuis et al. 2009). Figure 1 illustrates a cascaded loop in production. For this purpose, the respective input and output variables of the individual viewing areas are represented and analysed in their dependency and interaction.

Based on customer demand, production orders (quantities and dates) are generated and the batch size is set. Subsequently, a selection is released from the pool of applied orders according to certain criteria and passed to the production. If the released production orders are not caused only by appointment, simultaneously a sequence is determined. This implies the definition of certain prioritisation rules. As a result, on the resource level the machine scheduling and a specific assignment of staff deployment emerge. Depending on the existing flexibility of the production system, a capacity levelling is required. This is designed so that it enables a timely order completion (Nyhuis 2006).

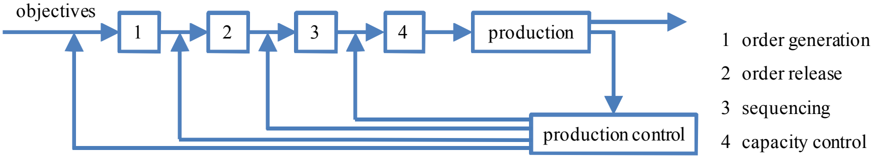

Figure 1: Cascaded closed-loop production control.

Though, unforeseen disorganisation in a production system necessarily means that its targets cannot be met. Consequently, intervention at an operational level in these cases is required to ensure compliance with deadlines. The need to control will always occur:

- when material leaves a considered production system,
- when the flow of material is divided,
- when material flows are merged and
- when the operating speed is changed (Dangelmaier and Warnecke 1997).

In this context, for the employees both informal and formal degrees of freedom apply in exercising their functions. Due to different priorities in production order acceleration in the various departments usually exists no overarching best practice. Moreover, bringing forward specific production orders always ensures that other jobs are delayed. Thereby, delayed orders risk becoming critical in respect of deadlines. Therefore, degrees of freedom as a function of the applied control method, the specific task within the production control as well as in consideration of the respective groups of people (production planners, foremen, and workers) necessitate a clear definition.

In this context, it is assumed that the formal rules of the production control in terms of their effectiveness are limited in multistage production systems. This entails other organisational rules for trapping occurring negative effects which cannot be confined by the typical production control.

4 POSSIBLE EXCERTION OF INFLUENCE OF PRODUCTION SYSTEMS

4.1 Hierarchical Model of Interactions

A major target for influencing production systems represents, in addition to production planning, production control. Production planning produces an image of the desired target state by the generation of default values for manufacturing and assembly. Empirically, the target state will not occur due to uncertainties as well as organisational and operational disturbances. In this context, production control ensures for compliance with the desired management objectives (lead time, capacity utilisation, inventory, on-time delivery) by intervening in current production processes. Furthermore, inventory significantly determines lead time and utilisation of the production system. The adherence to schedule results from existing backlog of production orders and changes in the original sequencing in respect of a schedule-oriented order release (Lödding 2008).

In this context, the question arises: to what extent it is possible to infer from the structural point of view of production systems to necessarily organisational aspects. Furthermore, the focus is on recognising the need for changes of production systems in terms of structure (elements and resources) or organisation (organisational structure and operational organisation) and answering the question of what changes are needed within the structure of production systems (type, extent and characteristics). Against this background, figures and scope of actions are subsequently determined pertaining to the different areas and elements of the structure of production systems.

As an extension of the approach of Zülch (Zülch 1990) it is assumed that certain interactions between the various functional areas within production systems exist (Figure 2). The production programme specifies production with a certain profile in terms of intrinsic value, timing and quantity. The temporal and quantitative profile is aimed predominantly at the customer demand and determines the production type. In this context, economic aspects are taken into account within a suitable production principle. Additionally, the resulting process principle contains both the temporal and spatial organisation of production processes. Based on the process principle, parameters can be defined for the cascading production control (Section 3.2). These parameters determine the strategic direction of the control principle (pull or push logic). Hence, the definition of the control strategy emerges.

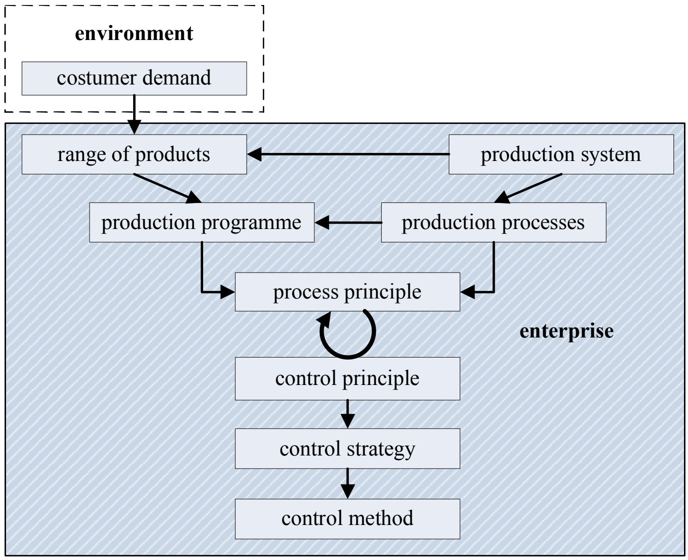

Figure 2: Interdependencies within enterprises.

In this context, the kind of order release, the sequence of production orders and the batch size are crucial parameters. The combination of these parameters enables specific control methods (e.g. kanban, load-dependent order release, etc.). Objectives, strategies and processes form obviously a hierarchical and self-similar system within production.

4.2 Combinations of Strategies

The selection of child elements is derived from existing constraints of the parent level. According to the presented task groups (Section 3.2), following strategies in the production control can be distinguished:

1. strategies for determining batch size
2. strategies for resource allocation (selection and scheduling)
3. strategies for sequencing
4. strategies for order release

In this context, a useful combination of the characteristics of the strategies is crucial. In consideration of organisationally robust processes, a limitation of the scope of action and the degree of freedom of the individual departments and process owners is required regarding sequence and priority of individual orders. This affects consequently the departmental job control in terms of self-organisation and self-optimisation (Hartmann 1995). Moreover, an establishment of a defined corridor of flexibility is necessary (see Focussed Flexibility by Terkaj et al. 2009). In this context, various aspects of changeability, such as convertibility, reconfigurability, flexibility, adaptability and agility (Wiendahl 2002), come into consideration.

Regarding the determining of batch sizes, the batch size usually is in compliance with the amount of corresponding production orders. A change in this initial state affects the temporal organisation of production. On the one hand, splitting batches enables a simultaneous processing of a production order on different machines or workstations. On the other hand, overlap allows the transport of subsets of one batch to the next processing station without waiting for the completion of remaining partial quantities. Moreover, batches can be merged or separated at defined operations due to technical or organisational reasons (e.g. heat treatment). With respect to resource allocation, a specific scope of action usually exists in terms of timing and quantities. In consideration of an allocation of production orders to particular resources, utilisation, effort for setting-up, length of processing time or the prompt availability of the resources are crucial factors. The sequencing follows generally certain priority rules. Without intervention, production orders would pass production processes on a first-in-first-out principle. However, a number of other rules for determining the sequence are possible. These are based in turn on the set-up time, the length of processing time, the planned completion date or other priorities set by management (e.g. importance of a customer). The order release can generally be done immediately or regarding a certain date. The date of the release depends primarily on the availability of equipment and personnel capacities or backward scheduling starting from the desired delivery date of the customer.

Moreover, measures of capacity adjustment in terms of time and intensity extend the scope of action. Apart from that, both an addition to capacity and a redesign of the temporal or spatial organisation of the production processes are worth to be considered. Thus, structural changes of production systems complement appropriate strategies of configuration.

5 CHANGES IN DEMAND OF PRODUCTION SYSTEMS

5.1 Trigger of structural Changes of Production Systems

The correct determination of an appropriate moment for taking structural measures, in particular aspects of organisational structure and operational organisation, is a particularly difficult challenge. In consideration of significant structural key figures (Section 5.2) and their changes over time, basic statements about the need for structural changes arise. Furthermore, respective control limits depend on the selected scope of action considering self-optimising production units. Thus, the need of structural changes equally necessitates detecting the appropriate moment for taking corresponding measures. The proposed approach aims at establishing robust manufacturing processes and procedures by identifying the most influential factors within production systems. Basically the following trigger come in consideration: CIP (shop-floor level), strategic shift, reorganisation due to environmental requirement (state policies, technology exchange), and organisational or operational disorganisation.

5.2 Identifying an appropriate Moment

Depending on the objectives (lead time, inventory, capacity utilisation, on-time delivery), appropriate levers for influencing the production system have to be identified. First, utilisation ratio should be used as a measure of process capability. It is the quotient of processing time and lead time. Moreover, the occupancy rate is of interest. The quotient of sum of execution times and lead time is a measure of the process linkage, thus also represents the amount of work in process. In addition, this ratio expresses productivity. Lastly, processing rate is a measure of process reliability. Consequently, the ratio of sum of processing time and sum of execution times represents the stability and robustness of processes (Kletti 2007). The proposed approach includes a hierarchical model, starting from analysing the production programme to specific control methods. Within this concept holistic control variables are identified that have significant influence on the specific production system. In this context, the concepts of self-optimisation and self-similarity represent two fundamental aspects of the proposed approach (Hartmann 1995).

Furthermore, the question arises: when becomes a production system (technical and / or organizational) in its organisation (organisational structure and operational organisation) and / or structure (system elements) inefficient or even obsolete that an appropriate change is inevitable? In addition, the kind of necessary changes (type / number / characteristics) of the production system has to be defined. For that purpose, parameters for stable and reliable production processes in terms of organisational and operational robustness have to be determined on the basis of objectives set by the management. In case of deviations and violations of the defined control limits, necessary structural changes can be differentiated as follows:

- No structural interventions (purely informational changes)
- Lightweight structural interventions (procedural changes: organisational structure, changing control parameters)
- Severe structural interventions (infrastructure-based, investment-oriented)

6 CONCLUSION

In this contribution, key levers and variables to influence production systems were identified. Furthermore, a hierarchical model is designed determining the parameters within cascade closed-loops. Based on the systematic drawn possibilities of intervention, the operational users will be in a position to act independently within coordinated control loops. In particular, this concerns the decision to exact specification of control parameters. Only the control limits are determined by management taking into account the company's goals.

The verification of this approach is in process. In this context, the concrete peculiarity of control variables considering different types of production systems will be determined. Accordingly, the questions mentioned in Section 5.2 will be answered. With respect to managerial objectives and the specific circumstances of a considered production system, interactions and interdependencies will be precisely analysed.

REFERENCES

Bergholz, M. 2005. *Objektorientierte Fabrikplanung*. Dissertation, RWTH Aachen.

Cordes, P., Hülsmann, M. 2013. Dynamic Capabilities in Manufacturing Processes: A Knowledge-based Approach for the Development of Manufacturing Flexibilities. In *Robust Manufacturing Control*, Lecture Notes in Production Engineering, ed. K. Windt, pp. 519-534.

Dangelmaier, W., Warnecke, H.–J. 1997. *Fertigungslenkung*. Berlin: Springer.

Dombrowski, U; Hennersdorf, S.; Palluck, M. 2007. Die wirtschaftliche Bedeutung der Fabrikplanung am Standort Deutschland. In *ZWF - Zeitschrift für wirtschaftlichen Fabrikbetrieb*. No. 1/2, pp. 14-18.

Hartmann, M. 1995. *Merkmale zur Wandlungsfähigkeit von Produktionssystemen,* Dissertation, University of Magdeburg.

Kletti, J. 2007. *Konzeption und Einführung von MES-Systemen*. Berlin: Springer.

Lödding, H. 2008. *Verfahren der Fertigungssteuerung – Grundlagen, Beschreibung, Konfiguration*. Berlin: Springer.

Nyhuis, P., Begemann, C., Berkholz, D., and Hasenfuß, K. 2006. Konfiguration der Fertigungssteuerung. In *wt – Werkstattstechnik*. Vol. 96, No. 4, pp. 195-199.

Nyhuis, P., Hartmann, W., Kennemann, M., and Münzberg, B. 2009. Produktionsregelung mit logistischen Kennlinien. In *wt – Werkstattstechnik.* Vol. 99, No. 4, pp. 239-243.

Schuh, G., Gottschalk, S., Lösch, F., and Wesch, C. 2007. Fabrikplanung im Gegenstromverfahren. *wt – Werkstattstechnik.* Vol. 97, No. 4, pp. 195-199.

Terkaj**,** W., Tolio, T., and Valente, A. 2009. Focused Flexibility in Production Systems. In *Changeable and Reconfigurable Manufacturing Systems,* ed. H. A. ElMaraghy, pp. 47-66.

Wiendahl, H.-P. 2002. Wandlungsfähigkeit – Schlüsselbegriff der zukunftsfähigen Fabrik. In *wt – Werkstattstechnik.* Vol. 92, No. 4, pp. 122-127.

Zülch, G. 1990. Fertigungssteuerung. In *Organisationsstrategie und Produktion*. München: gmft.