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USING A GROUP TECHNOLOGY APPROACH TO LEVEL A LOW VOLUME AND HIGH MIX PRODUCTION

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Abstract: The high variety of products and the low repetition frequency in job lot production can cause a great fluctuation in the demands for production capacity. Consequence of this fluctuation is a significant downtime of production facilities. State of the art for solving such problems is the Lean Production concept Heijunka, which means "levelled production". Leveling bases on manufacturing every product and character within a short periodic interval. The requested product diversity sets limits to the implementation of production leveling. At this point, the application of group technology offers the possibility to access the advantages of a levelled production. By means of group technology it is possible to classify products so that the product groups provide a basis for leveling. The product groups have to be generated in consideration of the possibility to choose every arbitrary subset without causing significant changeover downtimes between the productions of different characters.

1. INTRODUCTION

Companies of every line of business have to satisfy their customers needs and, in order to remain competitive on the market, optimise their capacity utilisation. Globalisation and the development from a sellers' market to a buyers' market have led to a new trend of demand. Today, customers expect individualised products and solutions at a "mass production price" (Thevenot and Simpson, 2004). At every time, companies have to meet their customers demands and requirements with the help of fitting solutions for all customer segments. As a consequence, product diversity is rising. Series production companies have to consider organisational and technical aspects of a low volume and high mix production. As a fact, the number of different product types (characters) offered to the customer rises, while at the same time production volume and sales amount of each single type decrease.

For a single product type, the high product diversity leads to a rather low repetition frequency and thus to an unpredictable, highly fluctuating demand for production capacity. Furthermore, machine downtime losses are increased because of a higher number of changeover processes. The manufacturer has to cope with these downtimes between the characters. Guaranteeing a short delivery time, companies build up a stock of finished goods to be flexible in meeting the individual demands of the customer.

Toyota concludes that, if the workload is not balanced, it is impossible to permanently adapt a production plan to fluctuating demands without over- or underburdening employees and machines (Jones, 2006). Consequences of an unbalanced production system are a constantly more complex control of production processes, a growing in-process stock and an increasing waiting time for parts due to unbalanced machine capacity.

The described problem shows the necessity to investigate workload balancing in a low volume and high mix production with the help of established "Lean Production" methods. In the Toyota Production System, a short delivery time despite a high product diversity can be achieved by the use of production leveling (Heijunka). Concerning series production this leveling concept is considered as the state of the art (Jones, 2006; Ohno 2005). The following points represent advantages of a levelled production:

- Reduction of worker and machine idle time as well as reduction of work in progress (Jones, 2006)
- Reduction of overburdened workers and machines (Jones, 2006)
- Backup capacities reserved for peaks of demand can be eliminated(Furmans, 2005)
- Establishing stable processes simplifies the implementation of further Lean Technologies (Jones, 2006)
- Improved visualisation of the production plan and a consistent pattern of planning (McKellen, 2004)
- The bullwhip-effect causing high levels of stock within the supply chain is avoided (Furmans, 2005; Lee, Padmanabhan and Whang, 1997)

The listed points show the importance of an adoption of production leveling to the low volume and high mix production. All items present a facilitation of production flow. They contribute to the avoiding of waste and increase the efficiency of the production.

2. CHARACTERISTICS OF A LOW VOLUME AND HIGH MIX PRODUCTION

Heijunka was developed for the production of rather small lots of big amounts of different products. Nevertheless, in a low volume and high mix production, the product diversity sets limits to the implementation (Ohno, 2005). In job lot production, a repetition frequency of 1-4 lots per anno can be regarded as a usual frequency (Willnecker, 2000). Additionally, an amount of 25 produced products of a type in total often is not exceeded (Schmieder, 2004). Under these circumstances, 5000 – 50000 different characters can be regarded as usual. This shows that in job lot production a low number of demanded items per character make a constant manufacturing of those characters inefficient.

Furthermore, the high product diversity causes complications, especially with regard to manufacturing and assembling. Effects concerning economies of scale, which are usually found in mass production, are rarely achieved. Another characteristic for low volume and high mix production is the chaotic order pattern caused by individual orders. The order size sets the lot size. Moreover, characters can have different work sequences and operating times which lead to changing shortages and a fluctuating capacity load in the production (Hesselbach and Menge, 2002). Avoiding this problem is one of the main targets of production leveling.

3. HEIJUNKA

The japanese term Heijunka stands for a method of production leveling and smoothing. Heijunka is part of the Toyota Production System (TPS). In 1990, by publishing the study “The machine that changed the world” written by James P. Womack and Daniel T. Jones of the Massachusetts Institute of Technology (MIT), the method was publicised for the first time (Womack and Jones, 1990). Furmans (2005) characterises leveling and smoothing as a “key element of the TPS” and thus strengthens its importance in that way.

Heijunka is an important basis for a lean production system. It gives a structure to the production line and reduces the risk of a capacity overload due to a chaotic allocation of orders. As stated above, the balance of workload provides a basis for further methods of Lean Production. Without the use of Heijunka, the existing fluctuations in demands make an implementation of standardised work or also Kanban impossible.

Heijunka aims at a balance of workload for both employee and machine (Vaghefi, Woods and Huellmantel, 2000). Production plans have to be organised in a way that certain amounts of all products can be manufactured in a repetitive production pattern within defined time slots (McKellen, 2004). The risk of causing structural overburden and idle times of employees and machines as well as the resulting overtime, shift allowance and further waste has to be avoided.

Leveling is based on the concept of manufacturing every product character within a repetitive, short periodic interval. The duration of this interval should be as short as possible. Within every interval, products are manufactured in the very same order. Consequently the production volume and the production mix are levelled.

This approach can only be successful if demand fluctuations are absorbed within defined limits. In the Toyota Production System, a buffer of finished parts is used for this purpose. This buffer contains all types of products and therefore is called “supermarket”. In order to dimension a supermarket, the long-term demand and the demand fluctuations of all products have to be determined. As in a levelled production the complete product spectrum is manufactured within short intervals, the supermarket can be rather small in most cases. In this means the peaks of demand are absorbed by supermarkets. The production runs smooth because of a continuous manufacturing of every product. Additionally, upstream production processes are disburdened due to the regularity of demand. The free capacity in these processes can be used to reduce buffers between production processes.

Especially the low volume and high mix production which is strongly affected by the handicaps of an unbalanced workload represents a great example for the existing room of improvement.

3.1 Enabling technologies for production leveling (Heijunka)

Several basic preconditions have to be fulfilled in order to implement the leveling concept in a low volume and high mix production. Toyota renounces high lot sizes in order to increase flexibility and assure a balanced workload for employees as well as machines (Becker, 2006). In job lot production it is easy to reduce the lot size as small to sizes are a typical characteristic of a low volume and high mix production. Nevertheless changeover times have to be minimised in order to produce small job lots in an efficient way (Sule, 1991). An application of flexible and adaptive production machines is required. Therefore, general-purpose machines are often applied in a low volume and high mix production (Schärli, 2006).

Besides these similarities there are also many differences. Pull Production and Kanban are closely connected with a levelled production. Investigations concerning the implementation of Kanban in job lot production show that an economical realisation is only possible by a standardisation of characters (Zäpfel and Hödlmoser, 1992). According to this, for the transformation of Heijunka to a low volume and high mix production it is necessary to have only a limited number of parts in certain production processes.

In order to absorb peaks of demand, production leveling requires a certain stock of finished parts. Due to the high amount of different product types, this is not convertible in a low volume and high mix production. In general, the fluctuations in demand connected with the high number of characters causes the storage of finished parts to be uneconomical. It is hard to give a proper forecast for individual orders (Plümer, 2003). This is the main difference in comparison to mass and series production which assume a constant sales development.

To be able to level a high mix production it is necessary to implement another element of Lean Production called effective variety management. A modular conception and a common part strategy enable a late specification of the product variant. In that way it is possible to level a production by establishing a supermarket which stores standardised components instead of finished goods. Demands of the near future can be satisfied by these supermarkets. But often it is not possible to reduce the number of different characters by means of product standardization. As buffering all components in a supermarket is impracticable, in this case a basic requirement for leveling is missing.

3.2 Interim conclusions

The previous paragraphs have demonstrated that an implementation of leveling (which means manufacturing every product character within a short periodic interval) in a low volume and high mix production is a desirable goal. But it is also shown that the characteristics of this kind of production are not directly suitable for the leveling approach. Due to the high product diversity and the fluctuations in demand the implementation of leveling can not be realised in a job lot production. As it may be impossible to reduce the number of parts to be kept in a supermarket with the help of product standardisation, a different approach has to be used. Thus, it is necessary to classify the numerous different characters into a controllable number of product families with the know-how and application of group technology. This approach is described in the following paragraphs.

4. BASICS OF GROUP TECHNOLOGY

The basic concept of Group Technology (GT) aims at the identification of a unique solution that solves numerous problems based on similar concepts, principles and requirements (Lee-Post, 2000). GT deals with the identification of similar objects or procedures in order to assign them to groups with similar characteristics. These characteristics are determined due to requirements of production processes in order to reach improvements on productivity. The grouping concept is transferable to almost all divisions of production. The broadly spread creation of manufacturing cells is just one application field of GT, but not the sole manifestation. Substantially, the success of GT depends on the classification of characters into product groups (Al-Sultan, 1997).

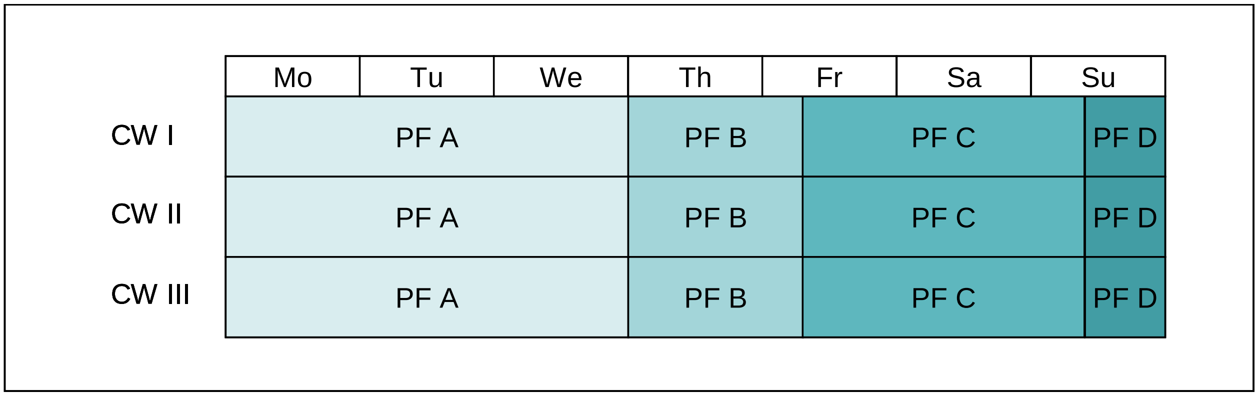

Figure 1. Heijunka Board

5. IMPLEMENTATION OF LEVELING BASED ON PRODUCT FAMILIES IN A LOW VOLUME AND HIGH MIX PRODUCTION

Due to aspects of variety management, GT has always been connected with variant production (Eversheim and Deuse, 1997). Originally, the intention of GT is to simplify the construction in terms of complexity reduction in order to facilitate the variety management. By means of GT characters can be classified to enable leveling in a production line on basis of product families. During each time slot only members of one product family are manufactured (shown in Figure 1). The selection of products depends on individual orders so that only a product family subset respectively is produced.

The generation of product families which are going to be levelled is based on significant similarity of process requirements of the different characters. In this way improvements on productivity can be realised so that even manufacturing of goods with high product diversity can be efficient and economical. To ensure this, all production families should have approximately the same production volume so that consistent production is guaranteed. In order to classify products and generate product families, criteria for characters have to be worked out. The respective intention of classification is decisive for the selection of criteria (Choobineh and Nare, 1999).

Lee and Fisher (1999) suggest classification of products which have an identical process time. This proves to be a suggestive approach, if a continuous workflow is aspired in the production process. The high potential of productivity improvements, which results from a continuous workflow, has been recognised in previous production systems like Fordism and Taylorism and has been adapted to today’s production systems. A consistent timing of products enables a synchronised supply of components for every production stage and a clock controlled transport to the next station.

Furthermore, changeover time represents a decisive criterion as small lots are a characteristic of low volume and high mix production and of a levelled production system. If several lots of characters are classified to product families, changeover proceedings between the characters appear nevertheless. Due to this fact, changeover time between products within a product family has to be as short as possible. But it is hardly possible to identify changeover times from each product to any other facing thousands of characters. This is due to the fact that the number of possible changeovers between products and hence the number of different changeover times increases exponentially by the number of characters. This problem can be solved using part lists. If two characters have a great share of identical components, a minor changeover time between these characters can be expected. Those products which consist of an identical part spectrum and have similar part lists are classified in one product family. The product groups have to be generated in consideration of the possibility to choose every arbitrary subset without causing significant downtimes due to changeover between the productions of different characters. This dependence on incoming orders implies the particular complexity.

If the two criteria, part lists and process time, shall be combined, weighting of criteria lends itself to a common classification (Lee and Chen, 1997). A high coefficient is assigned to the criterion which is of great importance for the enterprise, while a lower coefficient is assigned to the negligible one. But the achieved classification also causes difficulties. Due to a strict application of criteria weightings, without controlling the result with regard to plausibility, the efficiency is not secured. The process of weighting causes changes in product classification. Products which would not have been combined referring to the regarded target goals are classified into groups. An advantage of weighting process is the simplicity of application on further criteria as the process order and the required tool types (Lee-Post, 2000).
When product families are identified, the planning of a group-oriented production process requires three determinations (Jensen, Malhotra, and Philipoom, 1998):

1. Decisions referring to changeovers of machines to the next product group. Due to the determined time slots product groups are changed when the time slot of a product family has finished.
2. Decisions referring to machining sequences of product groups. The machining sequence of product groups is determined so that up streamed production stages are burdened constantly.
3. Decisions referring to selection of order within a product family. The selection of order of one product family can take place changeover-optimised. Therefore the similarity of part lists can be used too. As the characters of a product family are classified so that they are similar to each other, the date of delivery can also be considered.

After determining product families, the length of interval for a throughput of all product families has to be identified. The Experience shows that the interval should not be too short in the beginning. A huge interval minimizes problems concerning changeovers. If the production is synchronized to constant production slots, the length of interval should be reduced slowly in order to use the complete potential of levelled production.

After grouping products, general arrangements ought to be developed in order to assign new products to generated product families. Thus it is secured that new products can be classified in terms of generated product families (Moon and Kao, 1993).

6. CONCLUSION

By generating product groups, an establishment of conditions has been succeeded to adapt Heijunka to a low volume and high mix production. A data base which is required for the classification of products can be generated by means of existing data without additional data acquisition.

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