RELATIONSHIPS BETWEEN BATCH SIZES, SEQUENCING AND LEAD-TIMES

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Abstract: This paper treats the optimization of production batches by computer simulation in a manufacturing company producing electric and pneumatic actuators. In its introduction part the article deals about a wider context of batch production optimization. Subsequently, the paper presents a procedure for creation of a simulation model in SIMPLE ++ software environment. Based on simulation of a manufacturing process, selected dependences of lead manufacturing time on changes of production sizes was studied. As a result of optimization has been determined optimal minimal value of production sizes, by which minimal lead-time can be achieved.

1 INTRODUCTION

Manufacturing lead time reduction is one of the most critical issues in gaining a competitive advantage in the marketplace. Manufacturing lead time (MLT) can be defined as the time span from material availability at the first processing operation to completion at the last operation. Obviously, there are abundant reasons to reduce lead times in most organizations. Obviously, reducing MLT doesn't mean speeding up operation times, but all efforts should be focused on shortening changeover times, eliminating needless operations and reduction of production and logistical bottlenecks. Especially, batch sizes effect on MLT through changeover times. When using larger batches, then changeover times compared with the manufacturing times will be insignificant. Contrariwise, if applying smaller batches, then longer changeover times would reduce the capacity of the factory greatly. Research in this paper is oriented on the optimization of production batches by computer simulation in a manufacturing company, in which mentioned issues present a topical problem. The paper is structured as follows. After a short section on related work, the theoretical background is outlined. Then, testing of relations between batch sizes, sequencing and lead times is treated. Finally, discussion on obtained results is presented.

2 RELATED WORK

Importance of manufacturing lead times in generally depends on production policies. Manufacturing policy in this relation is associated with one of the two strategies: Make-to-Order (MTO) or Make-to-Stock (MTS). In a case of MTO, some products are commonly under extreme pressure, which creates a situation where certain products need to get priority over other products (Akkerman and van Donk, 2007). However, this prioritization doesn't solve problem with excessive throughput times in the plants. Thus, the same authors used the average lead time to investigate the effects of different product mixes. Fahimnia et al. (2009) analyzed obstacles in reducing manufacturing lead times and observed that relatively long MLT is the major cause of inefficient manufacturing, since it generates large amount of wastes and creates considerable environmental encumbrance. In a context of integrated supply chain, duration of lead time of original equipment manufacturers causes a different retailer's profit.

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Based on this assumption Mukhopadhyay (2008) studied optimal policies of retailers in different cases depending on the contract type with original equipment manufacturers. Guiffrida and Nagi (2006) focused their research on strategies for improving delivery performance in a serial supply chain based on evaluation of delivery performance. By them, ‘delivery performance is classified as a strategic level supply chain performance measure’. Instructive consequences formulated Wacker (1996): ‘If customer lead time is longer than manufacturing lead time, firms deliver from their production system and if customer lead time is shorter than manufacturing lead time, firms store finished goods inventory and incur holding costs’. A number of other authors studied the relationship between batch sizes and length of lead time. For instance, Kuik and Tielemans investigated the relationship between batch sizes and lead-time variability, or Millar and Yang (1996) analyzed relations between batch sizing and lead-time performance through the use of a queuing network model. Summarily stated, there are many options to achieve lead-time reduction.

3 THEORETICAL POSITION

In calculating the manufacturing lead time, the structure of the activities in production is one of decisive issue. Groower (1987) proposed to divide main production activities in two main categories, operation and no operation elements, excluding setup procedures that are generally required to prepare each production machine for the particular product. Thus, MLT is calculated as the sum of setup time, processing time, and non-operation time (Groover, 1987):

$$MLT = \sum_{i=1}^{n_m} (T_{sui} + QT_{oi} + T_{noi}) \quad (1)$$

where i indicates the operation sequence in the processing and $i = 1,2,...,n_m$.; T_{su} represents setup time for each process; T_o is operation (processing) time per item per process; Q demonstrates batch size and finally T_{no} denotes non-operational time including mostly waiting times for each process.

Equation 1 is considered only for one batch scheduling problem. For actual factory data, with its inherent variations in parameter values, equation 1 can be transformed to the multiplication process:

$$MLT = n_m (T_{su} + QT_o + T_{no}) \quad (2)$$

where Q and n_m are represented by straight arithmetic averages and variables T_{su}, T_o, T_{no} are calculated as weighted-average values.

Then, the formula for calculation of average MLT, can be expressed as

$$MLT = \frac{\sum_{j=1}^{n_Q} n_{mj}}{n_Q} \left\{ \frac{\sum_{j=1}^{n_Q} n_{mj}.\overline{T_{suj}}}{\sum_{j=1}^{n_Q} n_{mj}} + \frac{\sum_{j=1}^{n_Q} Q_j}{n_Q} \left(\frac{\sum_{j=1}^{n_Q} n_{mj}.Q_j \overline{T_{oj}}}{n_m Q.n_Q} \right) + \frac{\sum_{j=1}^{n_Q} n_{mj}.\overline{T_{noj}}}{\sum_{j=1}^{n_Q} n_{mj}} \right\} \quad (3)$$

where n_Q equals the number of batches, Q_j represents the batch quantity of batch j among n_Q batches, n_{mj} indicates the number operations in the process routing for batch j. In the weighted-average expressions individual symbols mean: T_{suj} - the average setup time for batch j, T_{noj} - average non-operation time for batch j and T_{oj} - average operation time for batch j.

Equation 3 is usable in a case when elements of non operation times are predicable. In case when applying a parallel batch processing approach, then previous equation needs to be modified. A parallel batch scheduling assume that batches are processed on machines in smaller lots, while for a serial batch processing is typical that all components are completed at a workstation before they move to the next one. If the batches are divided into N equal-size sub-batches, the idle time becomes (Kodeekha and Somlo, 2008). Accordingly, for a given problem we divided non-operational time to two groups: the *down time waiting for parts* – T_{nop} and *waiting time of parts in queue* - T_{noq}. Differences between these two methods are shown in figure 1.

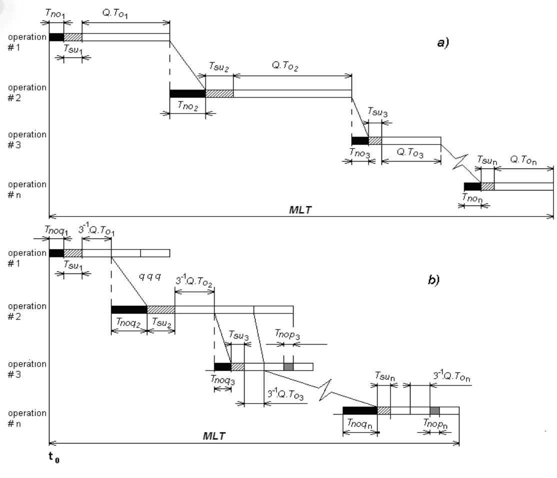

Figure 1: Time components of serial batch scheduling (a), parallel batch scheduling (b).

As is shown in figure 1b, item's manufacturing lead time of parallel batch processing legitimately consists of four components: setup time, processing time for given units in the batch, queuing time resulting from limited capacity, and down time resulting from component unavailability. Equating an item's MLT to its average manufacturing lead time may not be the best alternative because such lead times ignore the impact of lead-time variability (Mohan and Ritzman, 1998). Following the previous assumptions, then MLT for individual batches that are processed copying approach in figure 1b, can be computed by the formula:

$$MLT_{IB} = \\ = \sum_{i=1}^{n-1}(T_{sui} + \frac{Q}{N}T_{oi} + T_{nopi} + T_{noqi}) + \mathrm{T}_{\mathrm{sun}} + QT_{on} + T_{non} + T_{nopi} \quad (4)$$

where n represents the number of operations (or machines) of individual batches and N indicates number of sub-batches obtained from batch fragmentation.

4 TESTING OF RELATIONS

Testing of relations betweens between batch sizes, batch sequencing and lead times was conducted through computer simulation using SIMPLE++ (SiMulation in Production, Logistics and Engineering) software. A simulation model was developed to calculate individual lead times under different batch sizes and batch sequencing. Simulation model was specifically created for testing real manufacturing environment in a company producing electric and pneumatic actuators. In a manufacturing company, where testing was applied, 90 different products were taken under consideration. Those products are processed on modern machine tools and another machines and equipment in a batch manner with applying sequencing based on prioritization schemes. Batches during our experiment varied from 60 to 250 parts.

Simulation model composition, respecting the main optimization criterion to minimize individual manufacturing lead times, started with definition of two groups of objects required for material flow modeling. Defined were sets of 90 parts and 68 machines with single processing and multi processing ability. Subsequently, the general and detailed model of production flows at disposal to each product was designed.

Thereafter, loading of actual time values for each product in table forms with optional attributes was performed. Subsequent defined optional attribute of parts was size of batch.

From the predefined methods, as examples, the following can be mentioned:

- data input method, by which values of times related to individual part are assigned to the pertinent machine.
- output method that is functional for the purposes to allocate part routings to machine cells in compliance with a operation sequence prescription.

Mentioned relations through simulation experiments in the following order were tested. Firstly, it was detected, how a change from a serial batch processing to a parallel batch processing can influence the manufacturing lead time duration. To test it, all batches were gradually divided into N equal-size sub-batches where for batch #1 is N=1, batch #2 is N=2, batch #3 is N=3, batch #4 is N=4, batch #5 is N=5 and for batch #6 is N=6. In this experiment whole manufacturing lead time of all batches (MLT_W) was indicated. For the calculation of MLT_W it was applied equation 4 that is sufficient to cover the whole manufacturing lead time under condition that waiting time of parts in queue *Tnoq* is being calculated for all batches from t_0 (see in figure 1b) and that all machines and equipment are available for processing parts in time t_0 . Then the whole manufacturing lead time can be calculated by the following expression:

$$MLT_W = \max MLT_{IB} \quad (5)$$

Secondly, computer experiment was focused on learning influence of batch sequencing on whole manufacturing lead time. For this purpose, batches in above-mentioned six experiments were sequenced in two manners. In a first mode bathes were sequenced according to planned schedule. In the second mode bathes were allocated to processing machinery and equipment in a random manner.

The results from these two experiments are presented simultaneously in figure 2.

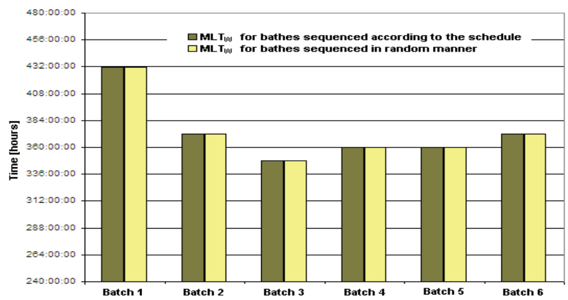

Figure 2: Whole lead times for different batches.

Another experiment was focused on comparison of MLT of selected individual batches due to the fact that changes in MLT_w between the manners of batch sequencing in the second experiment were not exposed. Therefore, individual first 5 parts for the next experiment were selected. Afterwards, batches of selected parts were gradually divided into batch #1 with N=1, batch #2 wit N=2, batch #3 with N=3 and batch #4 with N=4. Individual manufacturing lead times for given batches were calculated according to the equation 4. Evenly, as in second experiment, batches were sequenced in the same two manners. The results of these two experiments are shown in figures 3 and 4.

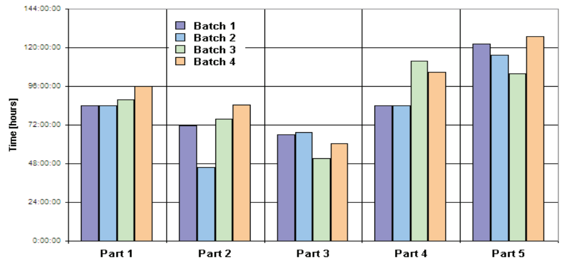

Figure 3: Individual lead times for different batches sequenced in random manner.

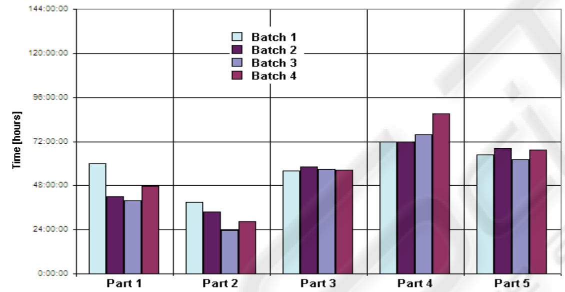

Figure 4: Individual lead times for different batches sequenced according to the schedule.

5 CLOSING REMARKS

Obtained results presented in figure 2 showed that size of batches in performed experiments influenced whole lead times. Moreover, local optimum solution of the problem between batch 2 and batch 4 can be identified. However, differences in MLT_w between batch sequencing manners in the second experiment practically were not ascertained. From the next two experiments it is possible to articulate that changes in MLT that was calculated for individual batches were influenced by different sequencing manners. Experimental results, which are demonstrated in figures 3 and 4, also showed that size of batches is influencing individual manufacturing lead times. Accordingly, in a given case there is no sense to modify sequences of batches, vice versa, it is reasonable to transform batches to the optimal sizes.

REFERENCES

Mukhopadhyay, S. K., 2008. Remanufacturing in Decentralized Supply Chains with Uncertain Yield: In *Proceedings Decision Sciences Institute 2008 Annual Meeting*, Baltimore, pp. 3531 -3536.

Akkerman, R. and van Donk, D.P., 2007. Product prioritization in a two-stage food production system with intermediate storage, *International. Journal of Production Economics*, 108, (1-2), pp. 43-53.

Fahimnia, B., Marian, R. and Motevallian, B., 2009. Analysing the hindrances to the reduction of manufacturing lead-time and their associated environmental pollution, *International Journal of Environmental Technology and Management*, Inderscience Publishers, 10, (1), pp. 16-25.

Wacker, J. G., 1996. A theoretical model of manufacturing lead times and their relationship to a manufacturing goal hierarchy, *Decision Sciences*, 27, (3), pp. 483-517.

Guiffrida, A. L. and Nagi, R., 2006. Cost characterizations of supply chain delivery performance. *International Journal of Production Economics*. 102, (1), pp.22-36.

Kuik, R. and Tielemans, P.F.J., 1999. Lead-time variability in a homogeneous queueing model of batching. *International Journal of Production Economics*, 59, (1-3), pp. 435-441.

Millar, H.H. and Yang, T., 1996. Batch sizes and lead time performance in flexible manufacturing systems. *International Journal of Flexible Manufacturing Systems*, 8, (1), pp. 5-21.

Kilpatrick, A. M., 1997. Lean manufacturing principles: a comprehensive framework for improving production efficiency. *Mechanical Engineering*. Massachusetts Institute of Technology, Cambridge, MA, February,

Groover, M. 1987., *Automation, Production & Computer Integrated manufacturing*. Prentice-Hall, USA.

Mohan R.P. and Ritzman, L.P., 1898. Planned lead times in multistage systems. *Decision Sciences* 29, (1), pp. 163–191.

Kodeekha, E. and Somlo, J., 2008. Optimal Lot Streaming for FMS Scheduling of Flow-Shop Systems, In *INES 2008 International Conference on Intelligent Engineering Systems*, Miami, Florida, pp. 53 – 58.