

Mastering Complexity in Manufacturing Scheduling

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With the beginning of the last economic crisis, Ortlinghaus-Werke used the situation as an opportunity to improve their internal processes and structures, more than what was possible in previous years where sales were much higher. Integration of the employees in the improvement process through motivation and participation in the success of the measures allowed the company to create an enterprise culture characterized by readiness for change and implementation strength. Cooperating with the Laboratory for Machine Tools and Production Engineering of the Technical University of Aachen, Ortlinghaus-Werke found a partner with whom they were able to develop and implement the concept for mastering the increased manufacturing complexity that has increased because of continuously more demanding customer requirements.

Starting point and goals

At the Wermelskirchen (Germany) location, Ortlinghaus-Werke produces brakes, clutches, and system solutions for diverse applications using single piece and small batch production. As in the past few years, manufacturing continuously improved its processes which allowed for a steady increase of the capacity usage and the production performance. Because of the increased individuality of customer orders and the increased number of manufacturing techniques in the past few years, the market has changed, demanding higher complexity in manufacturing. The introduction of an advanced planning and scheduling system (APS) for the detailed planning of the manufacturing processes should have helped to master the manufacturing processes. Very soon it became clear that such a system alone would not provide the desired success.

Because of this, Ortlinghaus-Werke has asked the Laboratory for Machine Tools and Production Engineering of the Technical University of Aachen to analyze and further develop the current concept of production planning at the Wermelskirchen (Germany) location. The main challenge was additional

reduction of order lead time, at the same time increasing the on-time delivery rate. Until then, the IT system with the implemented optimization algorithm had the effect that the results of the planning processes were not accepted by the employees because of their hidden nature. The results were calculated in the computer and no one could understand why the system came up with the outcomes it did. With the help of simpler, rule based control methods the goal was to increase transparency and give the employees a more important part in decision making of the control system.

Process Complexity as Key Determinant to Design the Manufacturing Control System

Ortlinghaus-Werke has a classical workshop based production principle as it is often seen in small and medium size enterprises. Because of the deep vertical range of manufacturing, most manufacturing processes are structured in several levels so that a high number of machines are actually involved in each section of the manufacturing process. The difference in operation times between individual process steps is sometimes very high. The same is true

for the lead time for sequential orders because of changing lots sizes. The actual value creation takes place on more than one hundred individual machines. As a result there are a high number of different pathways for the products throughout production. High fluctuation of capacity usage of individual resources is the consequence.

This process diversity in combination with different factors, for example changes in sequence of orders, is creating a high complexity in planning and control. So, it is safe to assume that there would be highly fluctuating order lead times, a fact that was confirmed by the analysis of data from individual manufacturing orders (Fig. 1).

The Challenge of A Complexity Optimized Manufacturing Control System

The classical dilemma of product planning and control is to achieve short order lead times and high sta-

bility of the production plan even in turbulent markets and fluctuating demand. For this purpose there is a whole series of IT tools that can be used. For example, supply chain management, enterprise resource planning system, and manufacturing execution systems, just to name a few. Especially the increased usage of Advanced Planning and Scheduling (APS) systems shows that enterprises have a high need for mastering complex processes because of the high dynamics. Based on real time data feedback from production, such systems can adapt themselves to changing characteristics of the process. Therefore, they can actually execute four different control tasks which can be defined as follows:

- a. Generation of an order has the greatest influence on work in progress in production. The main difference of the used methodologies is how a production order gets triggered. We can distinguish between triggering because of a customer order, triggering based on forecast, or by changes in warehouse levels. (Fig. 1).

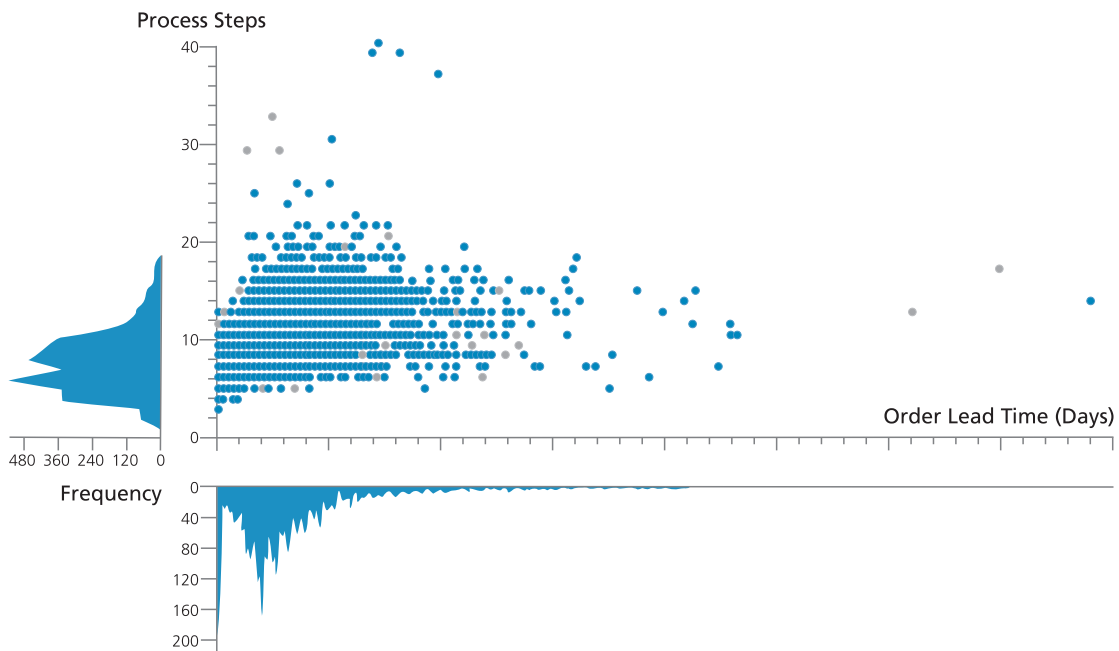


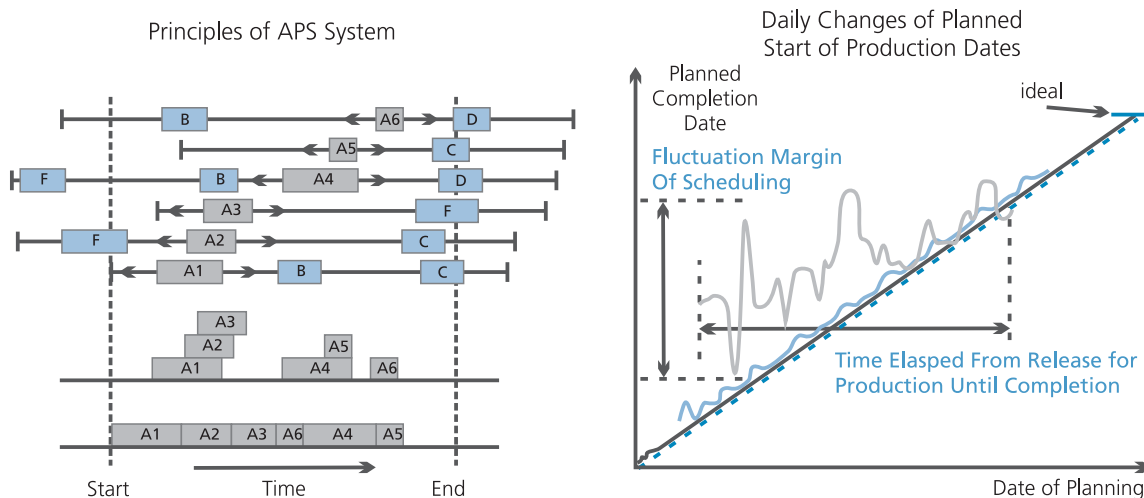
Figure 1: Distribution of Order Lead Time

- b. The order release is a task that is often underestimated in industry even though lean principles such as kanban or hijunka would actually lead the focus on the release of orders. The main difference is work in process, meaning materials sitting on the shop floor as well as capacity usage which in turn also influences the average order lead time. It is noteworthy that IT systems with strong support for this task are still not very common. The most MES and APS systems only provide methodology for an occupation planning of individual machines.
- c. The creation of a sequence in queues is influencing the distribution of order lead times and therefore also on-time deliveries. MES and APS systems fulfill this task at their core when production is better, more stable, and predictable. If work in progress levels are reduced, more simple rules for the development of the order sequence can be used. On the other hand, stability in complex production can also be enforced by

the usage of simple rules for the creation of sequence such as FIFO, first in, first out.

- d. The last task is the operative capacity planning and it is actually the longest lever for productivity and production cost. While bottlenecks are systematically opened up, the availability of personnel is uncoupled from the availability of machines, e.g. through cross-training and assignment of several machines to the same operator.

In the case of the Ortlinghaus-Werke an APS system was the central element of production control. The orders provided by the ERP system were converted based on work schedules and available resources, and were assigned a starting time in a way that allowed on time delivery in principle. Using this type of order release, a so-called machine occupation plan was executed by the APS system but the work in progress was not considered for the optimization of the plan. Only on-time delivery is the target criteria. This leads to the fact that individual process steps of an



Assignment of orders to resources creates interdependencies. Individual scheduling changes can have a major impact on other scheduled tasks.

Figure 2: Advanced Planning and Scheduling (APS)

order could be executed separately with long pauses in between as long as the delivery date was on time. Because of numerous predecessors and successors relationships, a highly complex work order system developed, which in principle, can be executed but is very sensitive against changes of any kind. On the right side of figure 2 we see the shift of a plant start time for a task over time. It is clearly visible that there is fluctuation of the target time frame which allows the conclusions that planning and control is very unreliable.

Based on the ideas of Deming, who did research using a funnel experiment to analyze how to master processes that are diverse, it can be shown that continuous adaptation in such a system actually worsens the situation. Only a fundamental change in the system structure which requires a deep understanding of the inner workings of the system can significantly reduce the fluctuations in the system. These possibilities are outside the scope of what the individual worker can do, therefore about 80% of all fluctuation problems are caused by the management.

The next task was using further investigations and analysis to identify true reasons and to answer the question whether such a control system is useful for the type of operation used in this example. Besides many influence factors, for example changing target times and short time order entry of rush orders, the strongest inconsistency for the development of an order sequence has to be identified. While the APS system provided a daily list of work orders to be executed on each machine, manual optimization of order lead time was performed at the same time on individual orders by changing the order sequence. Therefore some work orders from the buffer were expedited and others were held back. These changes of the sequence had a massive influence on the reliability of the planning process. They were the reason for many changes of planned delivery dates. They were the single most important reason for missed delivery dates, followed by changes of parts dimen-

sions and incomplete routers in the system. It was therefore not possible to comply with this highly detailed manufacturing schedule.

Even though APS systems have been successfully used in many applications there are two reasons why Ortlinghaus-Werke has decided against using them. First, as a result of the product complexity the quality of the material data was not good enough to control production orders. Secondly, the potential for improvement of order lead times and reduction of work in progress was not high enough. Therefore, a new concept for production control had to be developed.

An important part of production control concepts is the consideration of manufacturing bottlenecks. Bottlenecks limit the throughput of manufacturing orders in the system and therefore influence the work in progress. In literature there are several approaches to identify bottlenecks, however many of them are unsuitable for daily practice. For this reason Ortlinghaus-Werke has used the definition given by E. Goldratt, saying the bottleneck is characterized by the longest queue of orders in front of the process. Based on the available data from the shop floor it is possible to identify and measure the orders that are sitting in front of each machine and therefore identify bottlenecks. Because of the complexity of process flow it is possible that several bottlenecks exist in the same process. Furthermore, newly released orders can change the capacity situation so the bottlenecks are dynamic over time. In order to reliably identify the bottlenecks depending on the actual situation, Ortlinghaus-Werke has defined a bottleneck as follows: Any machine or process is a bottleneck if the work in progress in front of that machine is more than three days old or if the queue has orders in it that take longer than three days which have already been sitting there for more than three days waiting for processing. At the start of the analysis those conditions were actually true for 60% of all manufacturing resources.



Figure 3: Scheduling Board

The tasks of order release and sequencing that had previously been performed by the APS system now had to be performed by different methodology as the introduction of an additional IT solution was not suitable because of the problem described above. Therefore, a rule based production scheduling system was selected. This meant the scheduler had to come more into focus as the decision maker and he would need to be supplied with carefully prepared information in order to be able to make the right decisions. The most significant change was to no longer provide detailed order completion dates as had been provided by the APS system before. As such, information from the system had to be treated as a goal; it was always being used as excuse for not meeting delivery targets.

This was no longer possible with the new control concept. As a result, it became more important to be able to predict the order lead time and completion date which was only possible to achieve by reduction and fluctuation of order lead times. Fluctuation was reduced by simply applying the FIFO rule, meaning first in first out, which was integrated in the manufacturing layout as a restriction to always process the order that has been sitting there for the longest time.

The second element was the bottleneck oriented release of orders with a restriction on releasing additional orders while the buffer in front of a machine was still filled to a specified level. A key tool for this was a planning board that shows the work flow for every day and supports the scheduler with the needed information. At the same time increased awareness of all employees regarding the impact of changes in the order sequence improved the situation in a way that sequence changes only take place prior to the release of the order and delays of other orders are much more visible. In addition, the knowledge of the resource usage on each machine led to a changed approach from daily expediting of orders to a more holistic optimization of the production process. Step by step, WIP levels were reduced which in turn had a direct influence in the order lead time. In some areas the order lead time was reduced by 60%.

These remarkable successes are also a result of the many ideas that Ortlinghaus-Werke employees contributed into the change process to improve the work environment in the continuous improvement process and to continuously develop the manufacturing control concept further, e. g. by the implementation of new visualization tools.

Conclusions

An important part of this solution is the close monitoring of work in progress and waiting times. In conjunction with selected release of orders, even a complex production system can be controlled with relatively simple tools. This approach has already been used by Ortlinghaus-Werke with very good success and is continuously improved. Even though the individual elements of the solution have been known in theory for a long time there are no other applications in a similarly complex process that is documented. Experiences made with the development and design of manufacturing control concepts is highly valuable. Additionally, the cooperation between Ortlinghaus-Werke and the Laboratory for Machine Tools and Production Engineering also shows the importance of the excitement of all the employees with the application of the new solutions. That is the only way to ensure that there is uninterrupted development of new ideas that lead to continuous improvement.

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