HYDRO AUTOMOTIVE STRUCTURES EXPLORES "EVERY PRODUCT EVERY…" TO ACHIEVE LEAN BATCH PRODUCTION

Håkon Fauske[1]
Marco Semini[2]
Erlend Alfnes[2]

[1]*SINTEF Technology and Society, Operations Management, N-7465 Trondheim, Norway;*
[2]*Department of Production and Quality Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway*

ABSTRACT

This paper describes the use of the "Every Product Every…" principle in Hydro Automotive Structures Raufoss, a supplier of crash management systems in aluminium. The paper describes the process of development and implementation of the Every Product Every planning and control principle. The aim of the paper is to share experiences and knowledge from this process, and contribute to the application of Lean principles in batch production.

Keywords: Lean manufacturing, batch production, every product every

INTRODUCTION

Hydro Automotive Structures Raufoss (HARA) supplies the automotive industry with crash management systems as well as develops and manufactures bumper beams for almost all major original equipment manufacturers (OEM). HARA is a part of the Hydro group. Hydro is a Fortune Global 500 supplier of aluminium and aluminium products. Based in Norway, the company employs 22,000 people in more than 30 countries and is represented on all continents. One of Hydro`s business areas is the automotive industry within crash management. Crash management (front/rear) is one of the major applications for aluminium extrusions in the automotive industry, and plants dedicated to crash management are located in Raufoss (Norway), Louviers (France), Skultuna (Sweden) and Holland (MI, US) (Hydro, 2008). The supply chain from billet casting, through extrusion of profiles to forming and some machining operations are all situated in Raufoss. From Raufoss the bumpers are sent directly to the OEM, the assembly plants or third party logistics providers, before it's sent to the OEM.

The Lean process in HARA

One of Hydro Automotive Structures main improvement initiatives has been the implementation of Lean philosophy and practices. This work has lead to the development of the Hydro Automotive Production system (HAPS), an improvement programme, which describes their philosophy and steps to grow towards Manufacturing Excellence. HAPS is based on the principles of Lean Manufacturing and the Toyota Production System. HAPS consists of three pillars; Create Flow, Organise People and Improve Process. Through the work with HAPS, Hydro Automotive Structures Raufoss have seen major improvements at plant level in for example, changeover time reductions, 5S, continuous improvement work and visual management. The implementation of HAPS has not, however, achieved the Lean ideal of one-piece flow, zero inventories and production synchronised with customer demand. This is partly due to the challenges in implementing Lean principles in batch production, where production is characterised by long changeover times and high equipment utilisation. This paper describes HARA`s approach to this challenge, and their process towards Lean batch production.

The challenge and the solution

HARA have in the last few years experienced how demand fluctuations have caused rush orders in the supply chain, complicating supply chain coordination. The effect in each plant has been unpredictable plans, high work in progress inventory, difficult capacity and resource planning. To improve performance, HARA have decided to move from the existing Material Requirement Planning (MRP) to the adaptation of the Every Product Every (EPE) principle for manufacturing planning and control. This requires implementing a fixed production schedule that is rigidly followed Glenday (2004). The frequency of the cycles will differ between products, e.g. every two weeks, every day or every hour. The principle is based on the idea of implementing cyclic plans as a means to level production, improve efficiency and to gradually reduce batch sizes and move towards the ideal described in Lean as a one-piece flow. This paper will describe the development and implementation process of the EPE principle at HARA. EPE is currently under implementation in one of the bumper lines.

The research method is based on action research. Action research is the practice of both studying and analyzing a phenomenon while at the same time participating in development and improvements (Greenwood and Levin 1998). Together, the researchers and the project participants defined the problems and worked together to solve them. The change process was carried out through a series of workshops to analyse the existing planning and control system, and to develop and implement the EPE principle.

The paper is organised as follows. First we describe the supply chain planning and production processes at HARA with a summary of the identified challenges. Thereafter Lean and EPE theory and solution elements are presented. The final section of the paper describes the implementation process of EPE at HARA, and the evaluation of EPE.

SUPPLY CHAIN PLANNING AND PRODUCTION PROCESSES AT HARA

The supply chain at Raufoss is described in Figure 1 and includes a simplified material and information flow from the suppliers of ingot and alloy to the end customer. The process description is partly based on Kalsaas and Alfnes (2006).

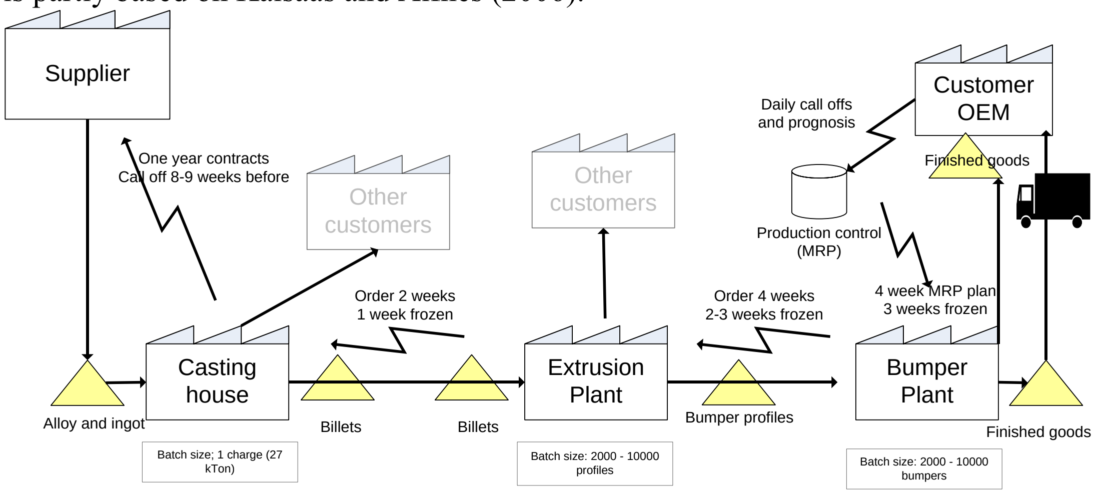

Figure 1 AS-IS map of the Raufoss supply chain.

The supply chain at Raufoss is a traditional supply chain with order based supply chain control. MRP calculations (based on customer call offs and forecasts) is the basis for a 4 week rolling production plan with a three week frozen period at the bumper plant. These plans are communicated to the extrusion plant which daily schedules production, based on a developed plan with a two-three week horizon. The extrusion plant develops orders with a one week frozen horizon and a forecast for the following week that is sent to the next tier, the casting house. In the casting house, production plans are made according to defined inventory levels and the orders from the extrusion plant. Products to other customers are made to order. The planning function in the supply chain has been traditionally organised with separate planning functions, and orders have been placed to the next tier according to demand and plans. Orders and plans have been communicated through email and telephone. Coordination meetings between planners have taken place, but with irregular frequency. The lack of collaborative planning processes, combined with different operational priorities in the supply chain, has lead to sub-optimisation with little synchronisation of processes across the supply chain. The result is a supply chain that is characterised by long lead times and high inventories.

Casting house process
The casting house supplies the extrusion plant with aluminium billets of different diameter, length and alloys. The internal value chain is made up of melting, fine tuning the charge, filtering, casting of cylinders, homogenization, sawing, labelling and packing. The raw material is ingot, scrap metal and alloying metals. The throughput time varies from 16 - 20 hours of which homogenization takes approximately 11 hours. One batch in the casting house is named a charge. A full charge weighs from 24 – 27 tons, and on average 4-5 charges are made every day. Only full charges are made to ensure high productivity (kg pr hours) and utilise capacity.

Extrusion plant process
The extrusion plant provides the bumper plant with extruded profiles in adequate lengths. The plant has two presses and two furnaces for aging. The internal value chain is made up of preheating of billets and dies, extrusion, cooling, stretching, sawing, labelling and packing. Some profiles are hardened before being sent to the forming lines in which the hardening process takes 5-32 hours dependent on alloys. A specific tool is applied in making a certain profile and the capacity of one tool is limited to a certain amount of profiles, before it must be changed. One batch of profiles can typically require 6-7 tools, and the changeover time between tools of the same product or to a new product is the same. To ensure high productivity (kg/hr) each tool must be used to its full capacity. Batch sizes are normally adjusted to the bumper plants batch size, but large batches must be split due to availability of tools. The throughput time of one batch depends on the batch size, but typically varies from 4-8 hours, not including the hardening process.

Bumper plant process
The bumper plant develops and produces bumpers and is a leading actor on bumpers made of aluminium in Europe. As of today there are today three bumper lines and the internal value chain for each line is made up of sawing, cutting, tempering, stretch forming, stamping, cutting and washing. The lines are manually fed while the rest is automated, packing and labelling included. The longest operation in the forming line process is hardening which last up to 20 hours. The batch size in production varies between 2 000 and 12 000 bumpers. Changeover time varies dependent on forming line. Productivity is measured in bumpers pr hour and large batch sizes are preferred as capacity is limited in periods. The throughput time of one batch is dependent on the batch size, but typically varies between 8- 24 hours, not including the hardening process.

Challenges in today's manufacturing planning and control
The supply chain described has several challenges in becoming Lean, producing in takt according to customer demand. One example is that the different production processes and operational priorities lead to different batch sizes and an unsynchronised material flow resulting in high inventories.

A major challenge for the supply chain has been its response to fluctuations in OEM demand. A typical scenario is when changes in OEM orders lead to new MRP calculations and subsequent changes in production plans for the bumper plant. This has led to rush orders throughout the supply chain. The effect in each plant has been unpredictable plans, high work in progress inventory, difficult capacity and resource planning. As a result of this, the supply chain was not synchronised, but producing products at different tact and in some cases producing the wrong product and creating unnecessary inventory, i.e. not showing the characteristics of a Lean supply chain. Fire-fighting has been the norm (for both operators and planners) and less time has been devoted to continuous improvement on the shop-floor. To further complicate the situation each plant, with its different processes, has had different strategies to achieve high productivity (e.g. large batches). Discussions regarding economic batch quantities and batch size coordination have taken place, but with few concrete results. Information exchange in the supply chain can also be characterised as traditional as only the bumper plant have access and use end customer demand in their planning. Extrusion plant and casting house receive market information only through orders in the supply chain, and planning is carried out at each plant.

In sum the situation could be described in the following points:

1. Change in customers orders caused frequent plan changes and rush orders in the supply chain, thus complicating supply chain coordination
2. Focus on high resource utilisation in each plant and. no coordination in batch sizes between plants, resulting in large batch sizes and subsequent high inventories
3. Traditional information exchange, with limited information transparency (only bumper plant can see customer demand) and lack of collaborative planning processes.

To meet the described challenges HARA carried out a set of workshops and training to come up with possible manufacturing planning and control principles to improve material flow. The variability of demand was identified as a key challenge and actions to counter this was prioritised. The goal was to achieve a levelled production of bumpers, where production was shielded from customers demand fluctuations. Based on several workshops and HAPS material, management introduced the Every Product Every principle, as the main manufacturing planning and control principle for the supply chain. In the following section, theory related to Lean and EPE will be described and its application in HARA.

LEAN AND EVERY PRODUCT EVERY SOLUTION ELEMENTS

One of the major principles in Lean manufacturing is Just-In-Time production, meaning that only the necessary products, at the necessary time, in the necessary quantity are manufactured, and in addition the stock on hand is kept to a minimum (Sugimori, et al. 1977). A complication factor in achieving this flow of products is the fluctuation in demand. The case in most companies is that the quantity withdrawn by the subsequent process varies considerably. As a result the processes within the company as well as subcontractors will maintain peak capacity or holding excessive inventory at all times. To overcome this challenge and making just-in-time production possible, the prerequisite is to level the production at the final assembly line (Sugimori, et al. 1977). At Toyota and other car manufactures this has lead to a levelled production schedule where the production sequence is carefully planned with regards to cycle times and material requirements. This has helped them achieve the final goal of one-piece flow matched to market pull through takt time.

The concept of Just-In-Time and one-piece-flow was designed for manufacturing plants that assemble products from many different parts, such as OEMs in the automotive industry. To batch producing companies the concept of one-piece flow is considered impossible due to their production system capacities, where resource utilisation is key and large batches is the answer. The challenge is how these, exemplified in the HARA supply chain, can move towards just-in-time production. Traditionally these companies use MRP systems in calculating the plans, focussing on efficiency and economies of scale considerations. When changes in demand and production breakdown occur, the plans are continuously changed while fire-fighting and chaos becomes the norm. (Mitchell, 2006). Achieving a level production with small batches in these companies is by many, seen to be impossible due to their process characteristics and often unstable demand. The following section describes how EPE can help achieve a level production in these companies.

The EPE principle is based on cyclic planning, and introduces a fixed production plan to increase plan predictability and to then gradually reduce batch sizes towards one-piece flow. Implementation of the EPE principle has the following solution elements:

- Levelling production and establishing cycles
- Determination of batch sizes
- From batch to one piece flow

Levelling production and establishing cycles

Glenday (2004) proposes that levelling of production is possible in a batch producing environment through the implementation of a fixed production schedule that is rigidly followed. This means making the same products, in the same sequence, in the same volume, on the same equipment, at the same time, with the same sequence, every cycle (Glenday, 2004). The effect of this is by Mitchell (2006) described as the best way of getting out of the vicious circle of fire-fighting and reduction in overall performance that constant fire-fighting brings. Establishing cycles can be done through a classification of products based on volume (ABC –classification). A possible scenario is presented by Glenday (2004). Similar classifications were done at HARA.

Table 1 Product classification for cycle development.

Cumulative % of Volume	**Cumulative % of SKU`s**	**Color code**	**Control principle**
50 %	6 %	Green	Fixed production cycle
95 %	50 %	Yellow	Attempt to include in cycle with green products
99 %	70 %	Blue	
Last 1 %	30 %	Red	Are these products profitable? Produced on dedicated machines or in specific slots.

This classification is a good starting point for a differentiated control of the products based on volume. High-volume products (in this case only 6 %) can be produced in a fixed product cycle every week (EPE-principle) and create a ”green stream” of products through the factory with short lead times and continuous flow. These products can be produced every week as demand is high and stable. This green stream is the main flow in production and establishes a rhythm for operators and support functions.

The yellow and blue products are more difficult to introduce in a fixed cycle as their demand is less stable. Dependent on demand and changeover time these products can be introduced in a fixed cycle, but with lower frequencies e.g. every second or third week. There can also be fixed slots in the production plan for these products, and where they will be produced if there is demand. For the red products it should be carefully investigated whether these products are profitable considering the administrative and production cost that incur from making these products. If they are strategically important, they can be produced in separate slots or on dedicated machines.

Determining batch sizes

An important part in establishing the cycles is the determination of batch sizes. Lean manufacturing literature states that batch sizes should be as small as possible and ideally one, as this supports Lean thinking of the reduction of inventories (i.e. waste), short lead times and production only on customer demand. Other quantitative models such as EOQ/EBQ includes inventory and changeover costs, but are heavily criticised due to its weaknesses and assumptions (see for example Hopp and Spearman (2001)). These models do however have to two major advantages – one is its simplicity, the other is the flatness of the function in the EOQ”zone” (Slack et al. 1998). This implies that the total costs are rather insensitive to deviation around the optimal batch point, and that the determination of the actual batch size is somewhat flexible. This means that other factors also should be taken into account when deciding batch size, such as coordination with supplier or customer. In the HARA case, some EBQ calculations were carried out and used as decision support, together with guidelines for batch size determination based on the EBQ model, presented by Strategos (2007).

Due to the EOQ/EBQ limitations, there are numerous attempts to develop mathematical algorithms for the determination of batch sizes in different production environments optimising inventory and lead times. Examples of these considering a cyclic production environment are for example Ashayeri et al. (2006) and Van den Broecke et al. (2005).

From batch to one-piece flow

Initially EPE results in more stable plans and a set rhythm on the shop floor. As this fixed cycle schedule is repeated, “economies of repetition” will start to emerge (Glenday, 2004). Routines can be established, so that work can be standardised and continuous improvement processes initiated. In batch production changeovers are especially targeted and will be improved. This improvement in capability and capacity will allow more products to be included into a fixed sequence, enabling the cycles to be more frequent, shorter and more flexible in order to progressively match volumes to actual market demands. The final result of this process will be a one-piece flow of products to meet customer demand. A key element in realising the EPE plan is the finished goods inventory buffer after the bumper plant that absorb fluctuations in demand. This does initially increase inventory, but is essential in creating stability on the shop floor as well as a stable collaboration environment in order to synchronise production in the supply chain. With this stability in place, focus will be on reducing changeover times to be able to reduce batch sizes, resulting in reduced inventory.

Glenday (2004) argues that establishing a fixed cycle is only a step on the way to achieve a one-piece flow. The process from a monthly batch production to one-piece-flow is illustrated in Figure 2. The HARA plants are currently in step 1-3 in this illustration, dependent on product.

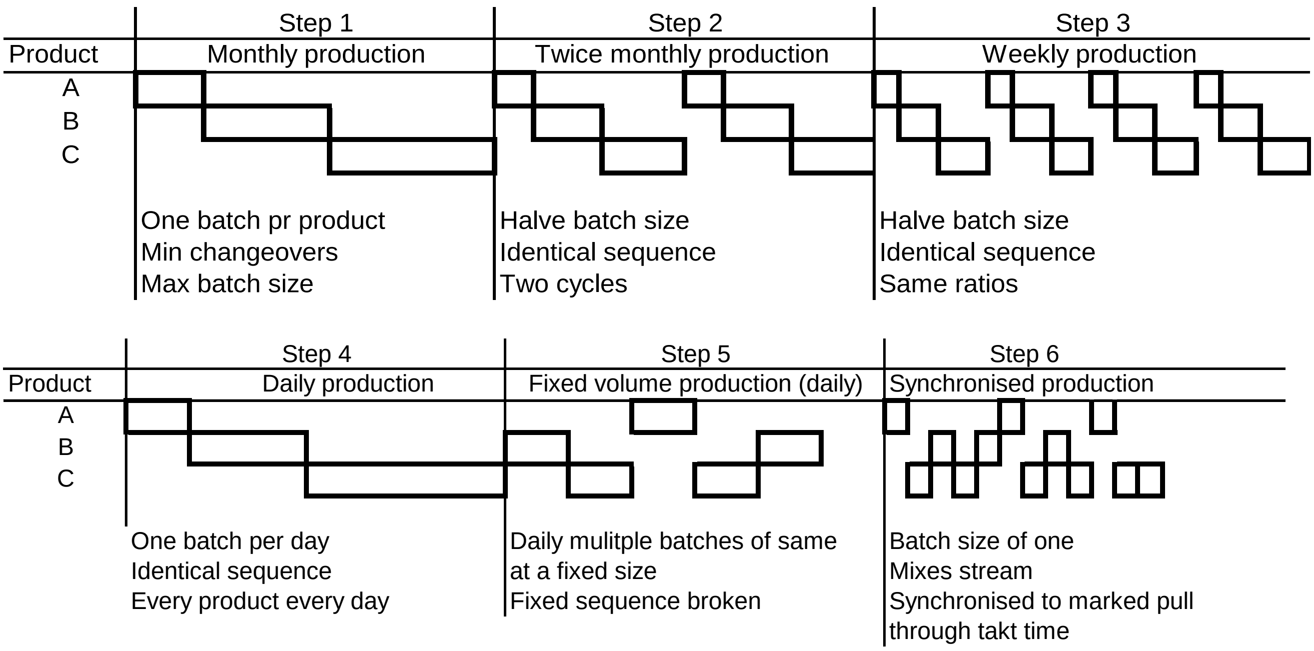

Figure 2 From monthly production to one piece flow (based on Glenday and Sather, 2005)

In Steps 1-3 a fixed cycle is introduced and the batch sizes are continuously reduced while frequency is increased for example from *every product every month* to *every product every* *week/day*. When a daily frequency is achieved, the fixed sequence can be broken while batch size is fixed (step 4). Some products are now produced in multiple batches daily. The final step is achieving one-piece flow with a batch size of one in a mixed sequence of products, synchronised with market demand.

Effects of EPE

Literature shows several examples of how cyclic planning principles have improved performance in single companies. Mitchell (2006) refers to companies like 3M, Wrigley and Kimberly-Clark where levelled production planning have resulted in increased throughput up to 30 %, reduced changeovers by 50 % and reduced wreck with up to 50 %. Schmidt et al. (2001) provides an illustrative case description where Alcoa implemented cyclic planning to manage capacity, increasing output by 20 %. For Alcoa the improvement in planning and production and maintenance planning contributed to improvements in; die changes, work-in-process inventory, machine maintenance, workforce planning and customer service. The plan was also the foundation for better coordination and planning of all related activities (Schmidt et al., 2001). Initially one should expect an increase in inventory due to the finished goods inventory that will be established in order to implement the fixed schedule. Other examples are also described in Suzaki (1987) and in Schonberger (1996).

Van Den Broecke et al. (2005) describes the benefits of common repetitive production plans in a supply chain. The predictability of the schedule allows synchronisation between the different production stages. In situations where capacity on selected resources is limited, a cyclic production schedule which distributes loads evenly on the operations will reduce the possibility of peak demands arriving all at once and claiming the use of the capacity constrained resource.

IMPLEMENTING EPE IN THE BUMPER PLANT

TO-BE manufacturing planning and control

Based on the analysis of the AS-IS situation the EPE principle was introduced and is illustrated in Figure 3 together with the vision of achieving a Lean batch production.

HARA saw that implementing EPE was an important step to achieve Lean batch production, characterised by a level and synchronised production, collaborative planning and improved material flow through reduced batch sizes. The first step in realising the vision was to implement an EPE plan in the bumper plant.

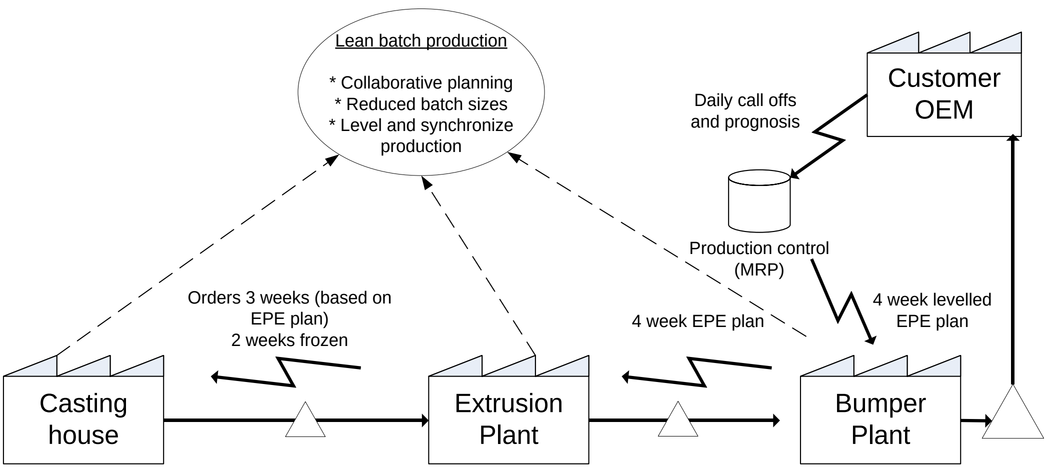

Figure 3: TO-BE manufacturing planning and control based on EPE

A four week levelled plan (based on the MRP plan) was developed, with fixed cycles. This plan would be communicated to the extrusion plant. Based on the EPE plan the extrusion plant can increase their planning horizon and also provide the casting house with plans with a longer horizon.

The EPE plan for the extrusion plant must incorporate demand from the bumper plant and other customers. In sum the new planning process will provide each actor in the supply chain with more stable plans that again results in increased predictability.

Implementation process

To ensure a good implementation, a four step process was developed in implementing EPE in each plant. The implementation has started in the bumper plant in one of the forming lines, in order to harvest experience and evaluate the principle. In the coming year EPE plans will be established in all forming lines and followed by the extrusion plant. The following section will describe the steps in development and implementation of the new plan. Step 1 is only carried out initially, steps 2-3 on a monthly basis and step 4 continuously.

1. Value stream mapping

First a value stream mapping activity was carried out by the operators on the specific press line to map material and information flow to e.g. find lead times and volumes. This process involved everybody and created a common understanding of the processes and the involved functions. The volume that goes through the system was estimated to find takt time and identify possible bottle necks. Results from the value stream mapping were important input when developing the plan, since specific constraints now could be allowed for.

2. Level demand

Based on customer demand and MRP calculations for a 12 week period, a level production plan for the next four weeks is developed, through a simple Excel tool. The planner updated the plan every four weeks to adjust for major demand changes. Cycle frequency and batch size was then reconsidered in the next step. High volume products (green products) formed the main product stream and the most frequent cycles.

3. Development of plan

Line capacity planning was carried out based on the levelled demand within the four week time horizon. Maintenance operations and spare part production (typically red or blue products) was also included in the plan. Determining batch sizes proved to be a challenging task, as capacity in some situations were limited and operators preferred to run large batches are minimise changeovers, as this was considered to be costly. Therefore an analysis of economic batch quantities, in both bumper lines and the extrusion plant, were carried out. These calculations showed that for the bumper plant the inventory and changeover cost were quite insensitive in a large interval and batch sizes could therefore be quite flexible. For the bumper plant it was important to utilise each tool, and this was the most important factor. These results provided important answers and guidelines in the development of the plans and batch size determination.

4. Implementing and follow up of plan

EPE has so far been implemented in one line in the bumper plant. The frequency between each batch differs between the different products, from every week until every fourth week. In order to realise the benefits of EPE, it is crucial that the plan is executed according to the planned sequence and volumes, to create the desired predictability for the supporting functions. HARA are experiencing several obstacles in the execution of the plan since there can be several interruptions to the plan, e,g. tool or machine breakdown, lack of personnel, lack of profiles or urgent changes in customer demand. To improve the adherence of the plan, HARA initiated the use of Statistical Process Control (SPC) to measure to what degree the plan is adhered to, i.e. if the products were produced in the correct frequency and in the planned volume.

Where there is a deviation from the plan the reason is classified into the category to which it is related e.g.; raw material, tools, planning, personnel, breakdowns or product defects. The results are discussed in weekly meetings with production management personnel (plant manager, team leader, planners etc.) and actions taken based on this. The result so far show that adherence to the plan varies substantially from week to week, with some weeks with only 50 % adherence to the plan to

100 % in other weeks. However, it does seem like there are trend towards, less variation and increase adherence to the plan, as the awareness and knowledge of this is increased in the organisation.

CONCLUSIONS

Evaluation of the EPE principle

At this stage in the implementation of the EPE principle in HARA, large improvements in the supply chain are not yet to be expected. Some effects have started to show in the bumper plant. There are now fewer peaks in production and some of the earlier constant fire-fighting to fulfil orders have been reduced. However, there is still a long way to go before HARA sees the effects that are described in for example Schmidt et al. (2001). Implementing EPE in the supply chain is challenging due to different processes and batch sizes. A starting point in achieving this would be to establish optimal cycles for the bumper plant, and then further adapt this to the extrusion plant. Due to long lead times and large batch sizes in the casting house, these products will be produced to stock.

The reduction of batch sizes to establish cycles and the idea of reducing them, proved to be challenging as personnel consider changeovers to be costly and therefore want to produce large batches. Discussion and analyses of batch sizes were important to show the effects and possible savings that could be achieved. This is however still an ongoing discussion. Another observation is the importance of adherence to the plan, as this will lead to the desired predictability for operators and support functions to perform their daily tasks and still have time for continuous improvement activities. This is crucial in order to realise the desired effects.

In sum, the EPE principles strength is its simplicity, in idea and approach, to Lean manufacturing planning and control for traditional batch producers. It provides simple guidelines to be adopted and cases have proved that potential huge savings could be realised through increased efficiency. Its main weaknesses are that initially new inventory must be introduced to be able to follow the cyclic plan, thus increasing lead time. Another challenge lies in our opinion in convincing people of the positive effects and how implementing a rigid plan will give them more flexibility.

Further work

In addition to the challenges in adhering to the plan in the bumper plant it is also important to analyse the effect of these plans on the supplier to the bumper plant, the extrusion plant. In sum the three EPE plans from the bumper plant will create a fixed demand pattern for the extrusion plant. This pattern can create difficulties for the extrusion plant as it can create unfortunate product mixes. Production planning in the extrusion plant is based on several criteria (e.g. product mix to balance oven, saw and packing operations) that can be difficult to match with the plans from the bumper plant. Development of plans must therefore be coordinated so that production in these two tiers can be synchronised.

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