Production Technology Requirements with Respect to Agile Manufacturing

A survey on how the metal forming industry can adapt to volatile times

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***Abstract* – Agile manufacturing is a production concept that was originally developed at the Iaccoca Institute of Lehigh University (USA). The purpose was to develop a proposal on how the US could regain its supremacy in manufacturing.**

The objective of this thesis is to apply the agile manufacturing concept to the metal forming industry and to develop a recommendation of action how the press manufacturers can support their customers in dealing with volatile markets in an efficient way. For that reason production technology requirements are developed that should highlight characteristics of a production line that is essential to become "agile".

As a point of departure a literature research has been carried out to determine what has already been published about "agile" production requirements and how other industries deal with volatile markets.

In a next step interviews with industry experts have been carried out to verify the findings of the literature review. The findings were documented in case studies which where the basis for the derivation of the production technology requirements that are relevant for the metal forming industry

Keywords – Agile manufacturing, metal forming, production technology requirements.

1. Introduction

During the last decade the manufacturing industry was faced with dramatic changes at an increasing rate that is expected to further accelerate. What makes this so alarming is the fact that these changes cannot be predicted anymore. These uncertainties and turbulent or volatile environments are believed to be the main reason for failures in the manufacturing industry. To survive and prosper in such an environment is only possible if organizations are able to recognize and understand the changes and furthermore respond, in an appropriate way. [8],[4]

In order to develop measures to do so the US government launched an initiative at the Iaccoca Institute of Lehigh University. The group consisted of senior executives of leading US companies and researches. The report, that was the output, focused on how the US could regain its supremacy in manufacturing. The result was a new production concept called "agile manufacturing". [8]

Agile manufacturing gained currency among practitioners and academics not only in the US but also in Europe and is expected to be a possible solution to deal with volatile times. [11]

It is one of the concerns of production management that quantities in manufacturing industry are gradually declining over the last few years and this tendency is expected to continue. This statement is true indeed, but has to be treated with caution as it is important to understand the reason behind that.

One cause is the decline in security of demand and of sales forecasts. This leads to orders being divided into smaller partial orders that are separated in time. [6]

Customers expect to always get the newest technology which accelerates the innovation cycle and with that the frequency of releases of new variants and face-lifts raises. This is also shown by the "Duration of product lifecycle" graph in Figure 1.which was taken from a study by Roland Berger Strategy Consultant. The average lifecycle of products across all industries (Automotive, chemicals, machinery, fast moving consumer goods, pharmaceuticals) decreased by 24% from 1997 to 2012 and is expected to continue to decrease. [6],[7]

The trend towards customization leads to more diversity of variants. Consequently the number of variants increase and the batch size decreases in an extreme case down to one. The graph "No. of sales

products" in Figure 1.describes how the number of offered products increased between 1997 and 2012. [6], [9].

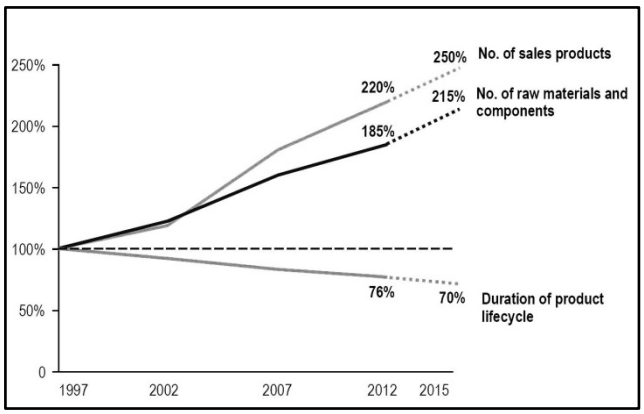

Figure 1: Increase of product variety across all industries [9]

To define the statement in the first paragraph of this section more precisely it is to say that even though the production quantity of individual products and variants of products decreased in the past and will continue to decrease in the future, possibly down to a batch size of one, the total number of produced products will not necessarily decrease. [9]

Knowing the reasons and the mechanisms behind the alleged decline in production, it is now the time to develop new requirements and tools to cope with the new situation.

2. Method

Literature has been reviewed to see which production requirements that are capable to deal with volatile times have already been described. As different terms are used to describe solutions for the same problem, production requirements for flexible-, reconfigurable and agile production systems have been reviewed. Also different areas have been considered like manufacturing machines or assembly lines. The literature review resulted in eleven production technology requirements.

For the empirical part, a survey with experts in the field of press manufacturing and metal forming from industry was carried out. The experts were two sales managers from press manufacturers and two managers from metal forming companies. The purpose was to find out if and to what extent the requirements of agile manufacturing found in literature have practical significance for the industry.

According to Yin and Albers a single-case design is the appropriate tool to challenge theoretical findings or to get insights into unexplored phenomena. In a single-case design the data of each case is gathered, processed individually (not compared to each other) and conclusions are drawn from the comprehensive picture obtained through all cases. [1],[10]

The style and structure of the interview is based on the so-called expert interview. Here the experiences and the interpretations of the interviewee have priority. The expert interview is a balance between openness and structure for data collection. To enable this balance an interview guide is used which makes sure that none of the important subjects are forgotten. [2],[3]

Out of these interviews the production requirements that are supposed to help the metal forming industry to deal with volatile times were derived.

3. Results and discussion

In the following, the production technology requirements that are important to the metal forming industry with respect to agile manufacturing are described. Even though most, if not all, of the found requirements are also important to other industry the structure and execution of the survey does not allow for a generalization. This is because the interview wasconducted exclusively with experts from the metal forming industry.

Throughput time

With a reduced throughput time the individual products get faster through the process. This is particularly important in order to be able to react fast and efficiently on product changes. In order to change the production from one product to the next it is necessary to first get all the old products out of the system. Only then the tools can be changed and the machine can be adapted to the new product. Thus a reduced throughput time cuts down the idle time during a product changeover.

As the number of products and variants goes up, these product changes occur more often. Consequently the throughput time becomes a pivotal criterion.

One attempt to increase the throughput time of press lines that has already been made is according to Mr. LotharGräbener from Schuler the so called cross bar feeder. In press lines the transportation of the sheet metal is typically done with industrial robots. These robots are cheap but require lots of space. This leads to presses being placed far apart from each other and, consequently, to longer transportation times. Also the quite big robot arms need a lot of space for manipulating the parts and require the tool to open wide. The cross bar feeder is a special purpose robot that was developed especially for the material handling within press lines and does not have the general disadvantages of the industrial robots. However, this is a more expensive solution.

Tool changeover

A fast and efficient tool changeover is a requirement that becomes important with the occurrence of different products and variants that are produced on one press line.
For smaller presses and blanking machines, systems have been developed where the tools are stored in high racks. This allows for an automation of the tool change similar to what is already state of the art for CNC machines.

These systems are not suitable for tools that are used in car body manufacturing due to the sheer size and weight of the tools. Programmable cranes are a possible solution. As the tools are typically stacked on top of each other, it is necessary to have storage logistics in place that allows getting the tools with as few movements as possible. Nevertheless, it will be necessary to have at least two industrial robots in place to be able to also get the tools that are stored underneath. The moving bolsters, which are already established in industry, perform the actual tool change right at the machine. For that an automated positioning of the tools and automated tool holders are necessary.

An important feature that cannot be forgotten in this context is the changeover of the grippers that transport the parts between the presses. Another important step related to a production changeover are the grippers that move the parts from one press to the next. Especially for high volume production it is state of the art to only produce parts on one press line that are very similar and can be handled by the same grippers. In small volume production, where lots of very different products are produced on the same press line within a short period of time, this is not possible anymore. In the future, with an increase of volatility, this problem will also concern high volume producers like OEMs. Consequently, for a fast changeover between different parts it is important to also adapt the grippers to the new part. In a first attempt flexibility can be achieved with automatically adaptable grippers that adjust the position and alignment of the suckers or magnets. This would increase the complexity of the grippers and with that the costs. The transformable attempt would be to automate the changeover of the grippers. The grippers are relatively small compared to the tools. Thus an automated storage rack could be used to store the grippers and get them from and to the press lines in an efficient way. On the long-term the latter would be less expensive as the costs for automation occur only once and the grippers could be as simple and inexpensive as they are now.

Add-on modules

On press lines different products with different requirements for the functionality of the presses (e.g. steel – aluminum, structural parts – outer skin parts) are produced. Add-on modules can be added to a press line when they are needed and removed after that specific job is done. They sure can be reused at another plant. This would allow switching functionality between different press lines when and where they are needed. Moreover, it would be a shift from a purely flexible machine which has a vast functionality to a transformable machine that has exactly the functionality that is required.

Add-on modules increase the utilization of modules and decrease unused capacity. Thus it increases the effectiveness.

Looking at aluminum processing examples for such modules could be:

- The grippers need to be changed from magnetic to vacuum as aluminum is non-magnetic.

- The transfer rolls for outer skin panels need to be made of plastic in order to avoid surface damage.
- Blank separation is done with an air stream to avoid surface damage.

Integrability

It becomes more and more important to be able to shift production between different plants and also to contract manufacturers. Looking on the product life cycle it might be useful to start the production of a new product on a small press line. This is because sales forecasts are not reliable anymore and thus no one knows how many units can be sold. When the product is established on the market and sales are high and stable it might make sense to switch the production to a bigger production line. Finally, at the end of the product life cycle when only spare parts are produced, the production might be switched to a contract manufacturer. The ability to allow for this shifting is a strategic and therefore an "agile" ability. A lot of different enablers on different underlying levels are necessary to be able to achieve this ability. On the production level, general industry standards are important enablers to allow for these fast shifts without adapting the interfaces of the tools and the software.

To be able to deal with a volatile market it will be crucial to further implement these standards all across the industry and to enhance integrability. Perhaps the most important example for integrability in the metal forming industry is a standard for the tool holder that is a key enabler to be able to shift the production to different press lines. Not forgetting the interfaces of the grippers with the robots that are used for material handling between the presses. Also the integrability of information (e.g. software) is important in order to avoid the necessity to recode the program for another machine. Of course, the add-on modules described in before need to be standardized and integrable in order to allow for a use at different sites. The term integrability that is used here is based on a concept by Koren.[5]

Diagnosability

The long-term vision is to have a control loop in place which automatically changes the parameter responsible for a defect that is detected at the end of line.
Especially when product changeovers occur more frequently and when different people operate the machines it is only natural that defects and problems occur more often. Therefore the ability to detect output defects and to react efficiently is an important production requirement. Diagnosability is, as Integrability, based on a concept by Koren. [5]

To this end, quality control needs to be automated with, for example, thermographic cameras, ultrasonic devices, ring tests or photometry. It is important that the used technology checks the parts fast enough to be usable at the end of the line. The pre-product (e.g. coils or blanks) can already have defects. Therefore, the incoming material needs to be checked as well. Also different critical process parameters like forces of the punch and temperature of the tools need to be monitored in real time. This huge amount of data can be used to understand the process better which helps to support error detection and elimination. Furthermore, a better understanding of the process helps to improve it.

If the data that is gained during the process can be analyzed and understood the parameters can be pitched like instruments of an orchestra to create synergies and enhance the overall result. The crucial point in the realization of such a system is to analyze and understand the data. A lot of literature that is concerned with this problem has been published lately, like "Big data - A revolution that will transform how we live, work, and think" by Mayer-Schönberger and Cukier. [7] Big data shall not be treated in this thesis in more detail but it is important to show the interconnectedness of the topics.

4. Conclusion

The here described production technology requirements are important enablers on the production level in order to become an agile manufacturer. If a company decides to adapt the agility concept it is important to start on the lower levels, as they are requirement for the higher levels.
Nevertheless, it will be necessary to continue research on this topic. First of all, it is necessary to define measures to fulfil the requirements and to implement these measures in the design of the press line.
In a next step, measures to achieve agility on the strategic level need to be developed. This means adapting the organization and the business model to volatile markets.

The road towards agility is still long and full of obstacles. As long as the markets are fairly stable it is not obvious why it is desirable to take the trouble and risk related to it. Nevertheless, if markets become volatile and unpredictable, companies that are prepared for them will have a crucial competitive advantage.

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