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MASTER THESIS

Equipment changeover reduction of a production line

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Production development, 15 credits

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Preface

This thesis work has been conducted during the spring of 2018, it is the final course of the Master's Programme (60 credits) in Mechanical Engineering at Halmstad University and supports 15 credits.

The authors would like to give a big thanks to all the involved in this project, without all the support and inspiration this would not have been possible. The knowledge gained from this work will help us through our careers after this programme.

A special thank you to:

Henrik Broström, Nils Larsson and all the involved operators at NIBE we would like to say thank you for your time discussing, answering our questions and the critique you have given us to help us improve ourselves.

Aron Chibba, for all the meetings, discussions, support during this thesis and experiences shared within this field we would like to extend our gratitude.

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Abstract

The growing competition for manufacturing companies is placing increased demand on fulfilling customer requirements with as high quality as possible as quick as possible. To meet the tougher competition, it is common that companies implement various tools and methods such as Lean Manufacturing, Continuous Improvement and Single Minute Exchange of Dies (SMED). Implementing these helps to reduce the risk of production failures while increasing efficiency thus increasing profit.

This thesis brings up the implementation of a tool within Lean Manufacturing called SMED to a production line with the aim to increase the machine availability through reduction of the equipment changeover.

The thesis is a qualitative case study where the authors use interviews, observation and time measurement to gather relevant data which are then analysed for the goal of this thesis which is to reduce the complete equipment changeover time of the production line in Ämnesverkstaden.

All the relevant data which was collected resulted in an implementation of a SMED mind-set and an instruction manual with a complementary list of necessary changes.

The authors believe that this study can provide useful information and knowledge when introducing SMED as well as an approach the operators can use in the future to help reduce the equipment changeover.

Keywords; SMED, Equipment Changeover, Lean, Set-up

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1 Introduction

1.1 Background

To survive in cutthroat competition, industries need to reduce production time and costs in order to improve operating performance and flexibility (Dave & Sohani, 2012). The ability to remain competitive and profitable requires you to be flexible and to fulfil the customers’ often specific requirement. Therefore the need of being able to produce a variety of products is considered a top priority. If an enterprise has a large product portfolio, there are basically only two process options; to integrate production into large batches or to change the production program frequently (Jan, 2016).

The changeover process of machinery together with the frequent changes the SMED (Single Minute Exchange of Dies) method provides is often considered a powerful tool to reduce the time between sets and through that being able to achieve frequent production changes. The company is only making a profit while the machine is processing the material (Chibba, 2017) is a very good mind-set and describes the purpose of SMED very well.

The authors of this paper decided to take use of the knowledge gained from their one-year master education at Halmstad University and put it to use in their thesis work considering changeover process at NIBE AB.

1.1.1 Presentation of the client

NIBE is a global concern who manufactures products and solutions for inside climate, intellectual heating and control within industry and infrastructure. The company operates within three different areas; NIBE Climate solutions, NIBE Element and NIBE Stoves and has a large part of their production in Markaryd, Småland.

From the start in Markaryd, NIBE has grown and operates in five continents with their 13500 employees. Under 2016 NIBE had a turnover of 15 billion SEK and is listed under the name NIBE Industries on Nasdaq Stockholm (NIBE, 2018).

Lindquist (2011), CEO of NIBE, describes their qualitypolicy by four major points: customer trust, zero defects, continuous improvement and demand of their suppliers. These points is something the authors will work towards in order to provide NIBE with the best possible solution.

1.2 Aim of the study

This project aims to reduce the time it takes to complete equipment changeover in their workshop called “Ämnesverkstaden”, to develop an effective plan and method for the employees to lean towards.

To achieve this, the method mentioned earlier named SMED will be used in this thesis. Within SMED two expressions are used extensively;

- Internal elements (elements that must be completed while the equipment is standing still).
- External elements (elements that can be completed while the equipment is running) (Moreira & Garcez, 2013).

The project will begin with a collection of data such as the time it takes to change equipment today, what volume that are produced, interviews with the operators about their own thoughts and how the communication between the shifts looks like.

With this data together with SMED the internal and external elements will be documented, discussed with the operators and the elements not considered to be necessary within “Internal elements” will be converted to “External element”.

The solutions which are presented by the authors will be compared to the ergonomic aspects of the operators to ensure that the work can be performed safely.

After the projects has been finished the equipment changeover times will be measured, the number of products counted, and the thoughts of the involved personnel collected and will be judged compared to the earlier collected data. Afterwards the result will be presented to the involved at NIBE and Halmstad University.
This leads to the research question stated in 1.2.1.

1.2.1 Research question

The goal of this master thesis project is to reduce the complete equipment changeover time of the production line in Ämnesverkstaden.

1.3 Limitations

With the limited timeframe and the guideline given by Halmstad University the authors decided to add some specific limitations to their own project for it to be successful.

- The project is limited to 15 credits which can be translated to 380 workhours.
- This report aims to reduce the equipment changeover for the production line “Excenterpressen” which is located in Ämnesverkstaden.
- If there is time after reducing the equipment changeover of Excenterpressen the rest of the production hall will be discussed with the operators for the purpose of implementing a better ergonomic workplace.

1.4 Individual responsibility & study environment

For this project the authors have decided to have equal responsibility for all involved parts such as: interviews, report writing, visits at NIBE and own reflections which might occur during the project.

During the entirety of this project the authors have access to an office at NIBE which will be used a couple of times per week, together with counselling from Aron Chibba at Halmstad University.

2 Method

This thesis aims to seek out the effect of an implementation of SMED regarding efficiency, cost and work environment. To be able to succeed with this an empirical study with observations, interviews and discussions together with collection of data such as time, workflow analysis and flowcharts will be done. This will give the authors a deeper knowledge not only regarding SMED, but the philosophy known as Continuous Improvement as well.

2.1 Method vs methodology

Research methods can be described as the tools, techniques or processes that are conducted during the entity of the project such as interviews, surveys and observations. What methods this project will use will be discussed in the later part of this chapter.
Methodology is the explanation of how the research is done, how the data is collected, knowledge gained and explains why certain tools are used in our project (McGregor & Murname, 2010).

One tool within the process improvement methodology Six Sigma is the DMAIC cycle which consists of 5 stages (Cherrafi et al., 2015) and aims to solve problems using quality and statistical tools, see *figure 1*. In this cycle the authors can acquire data during the production and find connections usable in the SMED methodology.

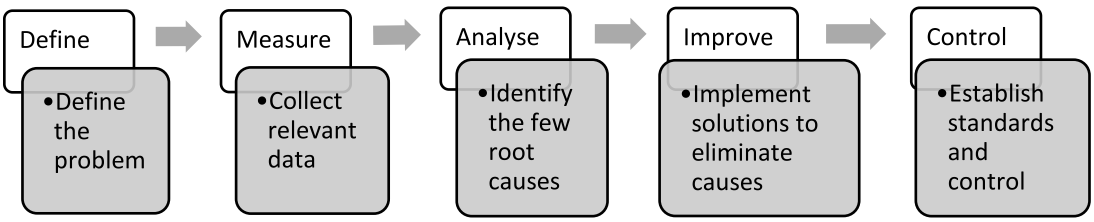

Figure 1. Define, Measure, Analyse, Improve & Control (Cherrafi et al., 2015).

The first step of DMAIC is Define which Borve et al. (2017) says is to explain, to amplify the meaning of and to set limits for a word or concept. This step will also help to clarify the problem being examined and the overall goals of the project by providing hints and associations that will relate the unknown to something know (Mark, 2017).

During the second stage “Measure” the authors observed and discussed with the operators during their work and carefully noted everything and in which order the operators managed their work. This data is then analysed using flowcharts and the elements is noted and discussed whether they can be converted from internal to external elements. The result of the separation of elements is then discussed with the operators and managers to find possible solutions which then will be

implemented. It is important to locate the few root causes during this step to help achieve the best result.
After the implementation of the improvements the time of equipment changeovers is then measured and compared to the earlier results to verify and validate the positive outcome of the work.
Subsequently of the verification and validation the need to establish standards and control is vital to sustain the positive implementations.

2.1.1 Qualitative vs quantitative method

With a clear goal and purpose for this thesis the decision to approach the task in either a qualitative or quantitative way had to be done early.

A qualitative method can be defined as to represent those techniques of data collection and analysis that rely on non-numerical data (Cassell, Buehrins, & Symon, 2006).
Yin (2014) mentions three questions at issue that is preferred when a qualitative study is at hand: The question form: “Who, what, where, when and why”, when the researcher(s) has very limited control over behavioural actions and with the focus on present problems.
As *figure 2* shows there is a significant difference when comparing the two different methods where both has their own strengths and approaches when solving a problem.

Qualitative research	**Quantitative research**
• The researcher is subjective, stays "inside" and often has long-term contact with the operators • The researcher is flexibel and the researchquestions is succecievly deppened. • The results goes in to the depth and applies to specific environments.	• The researcher is objective, stays "outside" and often has short-term contact or no contact at all with the operators. • The researcher is structured with questions which has been formulated in advance. • The result is general and variables clear, valid and reliable.

Figure 2. Qualitative vs Quantitative research (Olsson & Sörensen, 2011).

When quantitative methods are used the information is often considered “hard data” where the purpose is to describe and explain the measuring result. The researcher has an “outside” perspective with the task to neutralize the subjective elements and collect the desirable data as objectively as possible (Olsson & Sörensen, 2011). The reason for the quantitative study is to get a reliable average of the data.

For this project a qualitative method will be used for a couple of reasons. When visiting the operators and observing the changeover of tools, a close dialogue with the involved operators is often conducted. The project is as mentioned performed over a longer period of time where the authors believe a close relationship is preferred and helps with discussions and interviews as well. Since there is only two different operators working at the production line it would be hard to conduct a quantitative study as it would require more data than could be collected.

2.1.2 Approach

When conducting observations and measuring times in the factory it was very important for the authors to ensure that the operators would not be affected by their presence as this could affect the data. To achieve this, the authors studied the rules regarding visitors in the factory given to them at the first visit. These rules included what clothes to wear and precedence to the forklifts. To complement these rules the authors also added the rule that the operators always was in charge and that it was their schedule that would be followed.

The observations were taken by both authors simultaneous to increase the chance of seeing every vital area of improvement. An alternate for increasing the observational abilities further would have been to use digital means but since filming and pictures were not permitted in the factory this was not an option for this project.

The time measurements were taken between clear points in the process to attain as high consistency as possible across the measurements. For example, a set-up time would be measured from the moment that the operator retrieved the order to the point where the first punch was initiated.

2.1.3 Case study

The authors decided early in the project that a case study would help greatly with succeeding throughout this thesis.
Case study research is considered a qualitative method where the term qualitative refers to the fact that the researchers collect data in face-to-face situations by interacting with selected persons in a natural setting (Lillian, 2016). Case study methodologies examine a bounded system over time in detail, employing multiple sources of data found in that setting.

Using a case study methodology, the authors aim to gain knowledge of the process the operators use when changing tools for the next coming order. This includes every step from retrieving the order, programming the computer, retrieving material to changing the tool. Together with good communication through discussions and interviews with the operators a good and clear picture of the situation is can be presented.

2.1.4 Selection

This project was found through an acquaintance that informed the authors that there might be a project available at NIBE. A meeting was therefore set with head of production Nils Larsson to discuss possible projects and after a quick tour of the company it was decided that Ämnesverkstaden with focus on Excenterpressen had the best potential for both the authors and the company. The authors were then assigned to the responsible product manager Henrik Broström which then introduced them to the operators. Since only two of the operators work with Excenterpressen, all observations, time measurements and interviews were therefore restricted to them.

2.1.5 Gathering of data

As previously mentioned this project focused on a qualitative method and therefore needed a reliable source of information. This was achieved by the use of triangulation between different data gathering methods. Vanner & Kimani (2017) defines triangulation as the combination of multiple methods to study one phenomenon which are used to clarify, confirm and complete research findings.

Vanner & Kimani (2017) also warns users of qualitative research that there is a tendency to group together data into categories unconsciously set by the researchers. This could affect the outcome of the result as it can mask the need for additional data in certain areas and direct the data into a bias opinion of the researcher. Triangulation can be used to counteract this as it uses data from several sources to reach the result from different directions.

According to Vanner & Kimani (2017), there are four different types of triangulation:

- *Method triangulation* where multiple methods are used to collect data about the same phenomenon.
- *Investigator triangulation* where multiple researchers provide observations and conclusions.
- *Theory triangulation* where different theories are used to analyse and test the data.
- *Data source triangulation* where data is collected from different populations or types of people.

The data sources used in this project was time measurement and observations by the authors as well as interviews and open discussions with the operators (see *Appendix 1*). If placed into the types of triangulation defined by Vanner & Kimani

(2017), three of the four categories were used, those being *method*, *investigator* and *data source triangulation*.

2.2 Analysis of data

The collected data gathered needs to be simplified for it to be of relevance and analysed. Since the production line is operated by two different operators the importance to separate these with anonymity and for the data to be compared to each other is central.
Jacobsen (2002) claims that the steps needed for the data to be prepared for analysing are:

- Describing

After discussions and interviews notes of what was observed is added which helps to complement the raw data and makes it more comprehensible. With close contact to the operators the authors gained knowledge and insight of the process through the open interview and could build an own perception.
When observing the steps the operators made when demounting, planning next coming orders, gathering materials and mounting the machine reflections was also noted with eventual improvements and why each step was made.

- Categorizing

With the four “major steps” (demounting, planning next coming orders, gathering tools/material and demounting) flowcharts were made separately for both operators for it to be as easy to compare as possible. These steps were noted down separately and added to either the “Internal” or “External” element category (see *Appendix 2*). Together with the notes added during the interview (see *Appendix 1*) these could then be discussed whether it can be translated over from internal to external and therefor reduce the changeover time.

- Combination

During the last step described by Jacobsen (2002), the authors looked for similarities and differences by comparing the interviews conducted, observations and discussions around the two operators. This was done by an internal discussion by the authors and a second with the supervisors at both NIBE and Halmstad University which was then proposed to the operators for additional feedback.

2.3 Validity and reliability

Validity and reliability is vital regarding research, particularly in qualitative work where research findings are often questioned or viewed with scepticism by others (Brink, 1998). To give a lot of attention to these can be the difference between a good and bad research and will reassure the reader of the findings and results presented in this thesis work.

Validity in research is concerned with the accuracy and truthfulness of findings (Brink, 1998), a thesis work should confirm what actually exists and a measure should show what it is supposed to measure.
Campbell & Stanley (1963) have identified two major forms of validity:

- Internal validity, to which extent the research findings are a true reflection of reality and not of the effects of foreign variables.
- External validity, to which extent representations of reality are validly applicable between different groups.

Yin (2014) adds another form for control of validity:

- Constructive, the use of many sources as well as the origin of the source.

For this thesis the authors have used a number of sources. From scientific articles found on HH.se, books suggested by supervisors, discussions with operators as well as managers from different departments within NIBE and have been compared against research within the same field.

Reliability is concerned with the consistency regarding the stability and repeatability of the authors' ability to collect relevant data.
To achieve the reliability with the collection of relevant data the authors decided to create a clear framework for the measurements which was described in *2.1.2*.

3 Theory

In this chapter the authors will present relevant theory which this thesis is based on. The chapter is concluded with a discussion where the names theories are summarized as well as the ongoing research in the field of SMED.

3.1 Production development

The theory of developing and improving your production process is has its base in market competitiveness. Bellgran & Säfsten (2005) explains that both high quality and low cost is what wins the customers and is why it is so important in a company.

To help create the perfect production for a business one can use any of the different improvement philosophies, tools and methods that have been created over the years from different companies such as Lean Production, Six Sigma or Statistical Process Control (SPC).

Bellgran & Säfsten (2005) states that the term "Lean Production" is a name that was given by Krafcik (1988) to the production method that Taiichi Ohno had created for Toyota which they themselves simply called the "Toyota Production System". The principal of Lean is to eliminate all form of waste which enables a cheaper production with better quality products and through that achieve a higher customer satisfaction.

This makes Lean a good choice as a framework for the production process. One tool used in Lean Production is SMED which will be explained in 3.3. The negative aspect of Lean is that it is a long-term commitment and does not handle short-term problems that might occur. Reosekar & Pohekar (2014) would in those cases instead recommend Six Sigma which is a method that focuses on reducing unwanted variation in the production. This method was designed by Motorola by combining two other production improvement tools namely Total Quality Management (TQM) and SPC.

Jianjun et al. (2003) claims that SPC is often used in its original state within Six Sigma as a tool for identifying variations and their causes in the process. Rantamäki et al. (2013) explains that SPC itself is built upon numerous statistical tools which require some training in order to be used efficiently. If there is a lack of training in this area these tools might not be used correctly and could therefore have the potential to harm the system instead of helping it.

As these tools and methods are used with the same purpose in mind they can be used in conduction to triangulate flaws and problems in the company. For example, one could use Lean to create a mind-set for Continuous Improvement, as mentioned earlier, and to formulate the long-term plan. Six Sigma, SPC and similar tools could then be used to locate and solve immediate problems.

3.2 Equipment changeover time reduction

One major part of Lean Production is the theory of just-in-time production (JIT) which, according to Aghazadeh (2004), was developed by the Japanese in the 1970´s and handles the need for the ability to produce small batches of various different products to meet the rapidly changing market demands. Mileham et al. (1999) suggests that quick changeover times are essential to achieve JIT as it opens up the production and minimize the waste in time that occurs during changeovers.

Further benefits of a quick changeover are, according to McIntosh et al. (1996), that the flexibility and responsiveness of the production will be improved, as short set-ups allow for a greater selection to be produced each day which lets the company to offer shorter delivery times to their customers.

Bevilacqua et al. (2015) also points out that a quick changeover, and through that smaller batches, helps with the quality of the products. This is because quality checks as sample testing are more efficient on smaller batches since the samples represent a higher percentage of the total batch. This helps to identify problems or errors quicker which help to increase the total quality of the product.

The term “Changeover” can however sometimes be a bit loosely defined as to from which points you should measure the set-up between. McIntosh et al. (1996) describes it as the entire process of switching between the manufacturing of one product to the manufacturing of another up to the point of meeting the specified production and quality requirements for the product. This would mean measuring from when the previous batch is finished, to when the next is ready to go.

3.3 SMED-methodology

Benjamin et al. (2013) claims in their article that Single Minute Exchange of Dies (SMED) is a technique used to reduce the operational downtime losses of set-up and changeover of the production process. This is achieved by measuring and identifying the different parts of the process and separate the internal (parts that has to be performed whilst the machine is standing still) and external (parts that can be performed whilst the machine is still running) elements. Because of the effectiveness of this process Singh & Khanduja (2009) states that SMED now is a universal method used to reduce changeover times.

According to Benjamin et al. (2013) there are similarities between SMED and another philosophy called Overall Equipment Effectiveness (OEE) as both of them are used to increase the effectiveness of a changeover or set-up by eliminating unnecessary or non-value adding steps in the process. The terms changeover and set-up can be used interchangeably as both can be defined as:

“The process of switching from the production of one product or part number to another in a machine or a series of machines linked by changing parts, dies, moulds or fixtures.“ - (Benjamin et al. 2013).

Benjamin et al (2013) clarifies that a changeover or set-up is when certain tasks needs to be completed at the end of a series whilst the machine is standing still before the next can be resumed. This could for example be to exchange dies or material used in the process. This can be compared to the internal elements described in the SMED method. Changeover or set-up is measured between the last piece of a series is completed up to the first approved piece of the next.

The actual process of completing a SMED changeover can be argued but Benjamin et al. (2013) defines it with five steps:

1. *Separate the internal set-up elements from external set-up elements*. Here the total time for the changeover steps is measured.
2. *Separate the internal elements from the external elements*. Here the steps of changeover process are analysed.
3. *Convert as many internal elements as possible to external elements*. Here the process is changed so that as much preparation as possible is made beforehand.
4. *Streamline the remaining internal elements*. Here additional methods are implemented to further reduce the set-up time.
5. *Streamline the external elements*. Here the external elements are simplified. This is not done to improve the changeover process directly but instead to free the operators for other activities.

Because SMED is used to reduce downtime in a process Singh & Khanduja (2009) argues that it should not be implemented on a resource that is not a bottleneck. This is because reducing the changeover time of a non-deciding factor will have a limited effect on the process as a whole and could therefore only be a waste of time and resources. Non-bottlenecks are often also regarded as idle and would then already be working with excess capacities. It is therefore recommended to first analyse the entire process to identifying what parts are considered bottlenecks and focus on them.

Singh & Khanduja (2009) asserts that SMED also can be criticized for restricting the effectiveness of the method to a single machine and a single operator. They mean if SMED is applied to a workstation where two or more operators are working on one machine or if one operator works on several machines the actions implemented will be inconsistent. For example, if two operators are working on the same machine and changeover improvements are made for one operator by 50 per cent then the overall improvement on the process would only be 25 per cent as the second operator might not benefit from the changes. To counteract this instructions and manuals should be implemented in conjunction with the improvements so that all operators work in a similar fashion and can through that all benefit from the changeover improvements.

To summarize: SMED is a technique used to reduce the operational downtime losses of set-up and changeover of the production process by measuring and identifying the different parts of the process and separate the internal and external elements. Unnecessary elements are removed from the process and the remaining is streamlined to further decrease the changeover time. SMED should only be used on resource that creates bottlenecks and will need to be adapted if the changes involve more than one operator ore machine.

3.4 Implementation of chosen methodology

On average, engineers are known to be rather poor communicators and prefer the language of mathematics, computers and images to spoken words (Bohdan W, 2011).

When all the steps in the SMED methodology have been finished the changeover should have been reduced theoretically. Shingo (1985) describes SMED but does not describe anything about how the implementation of SMED should be done, how the operators are affected by the new work environment and how this affects the changeover. Shingo (1985) also mentions that the managers have a crucial part when it comes to the implementation of minor improvements.

Reik et al. (2007) mentions four different aspects of importance that has to be considered when working with implementation: processes, products, routines and people. SMED only focuses on three of these with the exception of people. Therefore, it is of great importance to not forget the last aspect since it is of equal importance as the other three.
Projects consisting of a SMED implementation often have a great impact for the operators and since SMED does not currently take into account the operators role it is possible that the SMED methodology could be complemented by theories consisting of this.

The most important aspects to succeed when implementing changes to a process is cooperation and communication from everyone touched by the change, from the operators to the management. To ensure everyone is kept in touch, involved with changes and the possibility to contribute with own thoughts and experience an infrastructure with clear goals and guidelines should be prepared (Henry, 2013). With a solid foundation to lean on created at the start of the project the chances of succeeding increases (Sörqvist, 1998). To avoid interference with the company's culture the project plan should be discusses thoroughly with both supervisors, managers and important key persons that are involved.

3.5 Ongoing research

SMED is one of many lean production methods for reducing waste in a manufacturing process (Yash & Nagendra, 2012). As explained SMED is an abbreviation for Single Minute Exchange of Dies, the phrase "single minute" does not mean that all changeovers should take one minute, but rather that they should take less than 10. When Shingo (1985) first started his pioneering work, it led to a remarkable reduction of changeover from 90 minutes to less than 5, today SMED is instead often used interchangeably with “quick changeover”. The authors would argue that the changeover reduction of 94% Shingo achieved is harder to achieve today since the lean philosophy has spread throughout the world which has led to companies continuously working towards continuous improvement.

This does not mean that the need of SMED is not worth reading into, there are studies arguing that the combination of SMED with other tools such as FMEA, Pareto analysis and statistical analysis (Stadnicka, 2015) can help to make SMED even more powerful. Stadnicka (2015) found that many companies still have difficulties with a long set-up time and do nothing to decrease them. To encourage companies to implement SMED it is essential to make analysis of changeover in order to discover problems. To do this Stadnicka combined tools such as FMEA, Pareto/statistical analysis to convince the management with a 7-step methodology to take action towards reducing changeover times.

The evolution of SMED has staggered off but still remains as the go-to tool to reduce changeover times. The authors believe that implementing SMED within a production line can definitely increase the efficiency but combining it with other philosophies or tools such as continuous improvement/FMEA can help to reduce the changeover even more.

3.6 Summary of theory

Production and process improvements are a necessity for a competitive business. To achieve this, a number of tools and methods can be used in conjunction with each other, because even if they use different approaches, the goal is the same for all of them. One vital method is changeover reduction which means minimizing down time of a machine by improving its use rate. To achieve the most efficient changeover one can use a tool called SMED which involves reducing the number of steps taken during the set-up and instead focus on preparations. Implementation of SMED can be a bit tricky though as it was created to function on one operator with one machine and often only see the different inputs (processes, products, routines and people) as numbers and does not take variations in these data into account. If SMED is to be successfully implemented, the entire cooperation of the workforce is required and everyone has to have the ability to contribute to the improvements.

The current research about SMED mentions the combination of different tools and methods that can be used in conjunction which can lead to a more effective approach to reduce the equipment changeover. Other than that the SMED process has not been improved further over the last few years.

4 Results

Here each action taken in this study will be explained and the result of these actions will be presented.

4.1 Implementation of SMED

4.1.1 Identify pilot area

As mentioned earlier in the thesis, the area selected for the implementation the SMED program is the Excenterpressen located in Ämnesverkstaden at NIBE. This equipment has significant room for improvement due to long changeover time, variations of the changeover process depending on what tool that is needed, and the operators are very familiar with the equipment and interested in improvements.

4.1.2 Identify elements

There are a number of tools that can be used for identifying the elements that the operators perform with video camera being the most useful (Steven, 2006). But since there is a ban of using any sort of video, the authors instead documented every step manually while observing.

4.1.3 Separate external elements

As there are different operators working on the same production line the authors decided to document both operator's elements and produce flowcharts to help identifying not only elements, as seen in *Appendix 2*, but the flow of the changeover as well (see *Appendix 3*).

The separation of elements was made while discussing and observing the operators with the help of the flowcharts performed earlier. Since a changeover is divided into four different stages (planning, set-up, during and demolition) the authors separated the elements within each stage.

Lastly the authors analysed the flowcharts and for each element the question "*Can this element, as currently performed or with minimal change, be completed while the equipment is running?*" was asked.
If the answer was yes, the element was marked with bold font, the rest remained as normal. This helped the authors prepare for the next step.

4.1.4 Convert internal elements to external

During the analysis of the elements, with the *Appendix 2* and *3* as reference, the authors could identify some of them that could be moved from internal to external. Since the authors already had prepared the conversion of the elements slightly during the previous step, the process to critically review the selected elements was significantly easier and helped to achieve a better result.

4.1.5 Streamline remaining elements

After the conversion was completed the process of streamlining both the internal and external elements began to help further reduce the changeover time. This includes reorganizations of inventory and help to prepare upcoming orders.
The final result was then presented and discussed with the product manager and head of production during a meeting who was satisfied with the conversion.

4.2 List of necessary changes

During the meeting with the product manager and head of production the authors presented a list of necessary changes as listed below. In conjunction it was decided what changes that was possible to implement immediately and what had to wait until a future date.

- Assistance tool to help with the positioning of the tool, *(Future change).*
- Add table with all the necessary equipment's for tool preparations, (*Present change).* This should include:
  - Grease gun to lubricate the tool.
  - Paper to clean the surfaces of the tool.
  - Should be able to clean the bottom of the tool
- More clear area for boxes, intermediate storage, finished products, *(Present change).*
- When attaching the crane to the coil the operators have to use the forklift because of lack of space between pallet and coil. Is it possible to use thicker sticks to give more room or thinner straps? *(Possibly present change)*
- Not enough room behind the press, makes it harder to fasten the tool, *(Present change)*
- When retrieving tools from the storage, is it possible to only remove the tool and not the pallet as well? If so, can a pair of shears for removing straps be placed at the storage? The storage would need reorganization so that the tools are more easily accessible with the forklift. Can a spot be reserved for pallets in the tool storage? *(Present change).*
- Able to prepare coil with the ability to remove already existing coil, *(Future change).*

4.3 Instruction manual

As described previously, the changeover is divided into four different stages: planning, set-up, during and demolition. After reviewing the methodology that the operators took during the equipment changeover, an instruction manual was created. This would help not only to create an optimal work process but also to help new operators easily understand and get used to a simplified changeover. This instruction manual can be viewed in *Appendix 4*.

4.4 Verification and Validation of the suggested improvement

After the new working methodology had been created and been approved by the product manager and the head of production at NIBE, it was presented to the operators for further feedback and to introduce them to the new way of working. When the operators had been given time to try it out the authors once again made observations and measurements to see how well the implementation had gone.

What was observed was that the operators had introduced some elements of the new methodology but not all of it. This can be due to lack of faith in the new methodology or that the authors did not convey the authority to make all of these changes. In spite of this, the implementation of SMED still had a positive outcome which will be discussed further in 4.5.

4.5 Analysis of the impact of SMED

Despite the incomplete implementation, the impact of SMED has been successful. As can be seen in the interview answers the operators had never worked with changeover reduction of any sort. With this, the main impact this project has been the mind-set of the operators. A clear improvement was noted when observing the operators performing a changeover as well as discussing with them afterwards.

As can be seen in *Appendix 5* a clear improvement is noted. Before the implementation of SMED the changeover time for set-up was approximately 34 minutes, this has been reduced to approximately 31.5 minutes.

5 Conclusions

In this chapter the authors will present conclusions which are related to the research question.

5.1 Conclusions

The goal for this thesis has been to reduce the complete equipment changeover. To succeed with this goal the authors chose to develop an instruction manual (see *Appendix 4*) for the operators to lean on. What the authors have noted during the observations, discussions and the SMED-methodology have resulted in a broader view on equipment changeover for the operators which has led to a continuous improvement mind-set.

After discussion with Henrik Broström and Nils Larsson the list of necessary changes was sorted into two categories: *Present changes* and *Future changes*. For the time being, the necessary changes classified as *Present* were improvements that could be implemented today whilst *Future changes* would be reviewed as they installed a new machine in the future.

The change that the authors believe would improve the equipment changeover the most would be the table with all the necessary equipment's for tool preparations. This would mean that during a run the operators could retrieve the tool for next coming order, place it on the table and perform the necessary preparations for it which would contribute to a more effective changeover.
This was later discussed further with Henrik Broström who suggested this to be placed as a *Future change* due to the cost of the table would exceed the benefit that it would bring within the timeframe until the machine exchange.

While observing the operators work the authors noted the lack of areas for boxes (empty and with finished products) and how this affected the overall flow in the work hall. If a clear area for intermediate storage were planed and implemented the operators would not have to jostle their way through while performing a changeover which would increase the productivity and effectivity.

When the operator picks up the tool from the storage the authors noticed a number of unnecessary steps. Today, the operators use the forklift to take down a tool which is bound to a pallet with steel wires, these are placed by the maintenance personnel after the regular maintenance of the tool. To separate the tool from the pallet the operators has to cut off the steel wires, throw away the scrap and then lift the tool from the pallet. The authors suggest that the operators remove the wires directly when they arrive from maintenance to make it possible to directly pick up the tool from the storage.

5.1.1 Recommendation to future activities

As mentioned before, the biggest contributor for reducing the equipment changeover is the preparation of next coming tool. Since the preparation table were put as a future change, the authors would like to recommend reviewing the new machine and design a proper table for the operators to clean and prepare the tools on.

The authors would like to suggest the continuation of working with continuous improvement and enlighten the operators of the impact this can have on reducing equipment changeover. To always work towards being more effective and spreading knowledge can widen the view of the operators which will make the work more intriguing. It is clear that (after talking to the operators) the mind-set is somewhat changed compared to before. From being "static" and only doing what is expected to challenge themselves and seeing potential improvements is something that is vital for growing, not only as an individual but as a company as well.

Since the implementation of SMED gave the immediate result of a reduction of 3 minutes the need to continue with the future changes as mentioned in 4.2 is necessary. With the implementation of the suggested future changes, when installing the new machine, the authors calculate the equipment changeover to reduce with an additional 7 minutes. This would lead to an equipment changeover to 24 minutes down from 34, an approximate 30% improvement of the original time.

5.2 Reflections concerning the process of change

The operators working at Excenterpressen has different methods when performing an equipment changeover. Because of this, the variation of the changeover time differs significantly. This variation makes it hard to measure and therefor implement improvements which increase the effectivity. By implementing a standard, a foundation is created for both experienced and newly employed operators that help to create a routine for a more efficient working method.

It has been noticed that the operators were sceptic towards working with changeover reduction at the beginning of this project. This may be due to lack of interest and knowledge regarding improvement tools, unwilling to leave the old way of working since "it has worked so far, why change?" and the inability to see the long-term goal.

6 Critical review

Here the methodology and execution of the thesis will be discussed and criticized.

6.1 Work environment

For this project the authors spent about 4 hours, 2 days a week at NIBE where they also had access to their own office. This was because, as mentioned earlier, time measurements were taken at Excenterpressen to identify parts of the process in which improvements could be made. This was at times difficult as the authors were not always present when all changeovers were conducted. The reason for this was partly because Excenterpressen does not have the top priority in the production hall and therefore does not always run, but also because of the long cycle times that Excenterpressen has which goes up to about 4 hours.

These two facts combined made it ineffective to sit at NIBE and wait for the next changeovers which might not even come during that day. The authors therefore decided to rely on communications with the operators and focus on planed changeovers. Another reason for the authors not always being present was because of swift demands from the rest of the company to which there was no time to contact the authors or for the authors to get there. If more time had been reserved for stating at NIBE it might have been easier to find the time to take the measurements. That would however create a negative effect on the authors' studies as a whole instead as the time spent waiting at NIBE would have turned into downtime on the other courses.

6.2 Alternative methods

Earlier the difference between qualitative and quantitative methods were discussed where qualitative means to do it in a careful and efficient way while quantitative is to do a more large-scale study. For this thesis the availability problem, discussed in 6.1, made it impossible to conduct a quantitative examination and so the authors had to rely on a qualitative approach. It was however still difficult to make enough measurements to make a reasonable study. More data could have provided a better result with a deeper understanding but would, again, require more opportunities to take measurements.

6.3 Societal perspective

Energy and environmental losses are something that has become a major trend in today's society. For manufacturing companies that means that they have to reduce the environmental impact they produce as well as make their production more efficient and less energy consuming. Through a continuous improvement mind-set and a minimization of waste, both of these aspects could be achieved.

This mind-set and efficiency can also help to relieve the personnel of stress which will create a more satisfying workplace. A continuous improvement mind-set can also help to forge a better relation between employers and employees as one is encouraged to communicate within the company. This will help to further improve the workplace environment and through that help the company to become even more efficient. The ISO-standard 14001 can be used as a reference for this since it describes how to improve the workplace environment through clear workplace frameworks and how to use the production improvement process to increase employee satisfaction.

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Appendix 1 - Interview questions

(Scale 1–5 where 1 means: does not work at all and 5 means: works perfectly)

1. How long have you worked at NIBE? _______________
2. How many years have you been working at this position? _______________
3. Have you been working with changeover reduction before?

   Yes No

4. Do you think there is a need to work with changeover reduction?

   Yes No

5. How much time do you think a changeover takes today?

   ____

6. How well do you think the communication between the shifts work?

   1 2 3 4 5

What do you think needs to be improved?

7. How well do you think the communication between you and the management work?

   1 2 3 4 5

What do you think needs to be improved?

8. Is there anything that you lack that would facilitate your work?

9. Do you experience your work as stressfull?

   1 2 3 4 5

10. How well does your current method for the changeover process work?

1 2 3 4 5

11. Do you have any suggestions for how the changeover process can be improved?

Thank you for your feedback!

Answers on interview questions OP1

1. 16 years
2. 10 years
3. No
4. 4/5
5. Ca 1h
6. 5/5 - 3/5
7. Etch number plates in black plate. Modernise
8. 3/5
9. Pretty good
10. Easier to mount tool, some sort of roll system for the tools for simpler installation

Answers to interview questions OP2

1. 9 years
2. 3.5 years
3. No
4. Yes (4/5)
5. Ca 2h
6. 5/5 (They usually call the day before and talk) (There is a small overlap)
7. 4/5
8. More info about service, should appreciate if you would get info when the service guy shows up. Sometimes he just shows up. (Planning, documentation, visual visible?)
9. 3.5-4 / 5
10. Works well, do not think that it differs that much between the operators.
11. The input lift of the coils is not parallel with the reel works, if there is a smaller inside diameter (coils) the input lift cannot be used at all (have to use the crane instead (Happens rarely but has happened))

Appendix 2 - Identification of internal and external elements

Text in fat cursive is elements the authors want to change to external elements.

Operator 2 - set up

Internal elements	External elements
Mount coil	Check order
Mount support for coil	Retrieve coil with crane
Cut off diameter band	Cut off sideband from coil
Set pressure in feeder	
Lead in coil to feeder	
Roll out extra sheet	
Clean the work surface	
Select program	
Check program	
Retrieve tool	
Untie tool from pallet	
Set aside pallet	
Clean and lubricate tool	
Lift up tool to work surface with forklift	
Adjustment of position of tool by hand	
Fixate tools	
Check stroke length with paper	
Mount ramp x2	
Led in coil in tool and measure first stroke	
A manual cycle with visual control	
Place output box	

Operator 2 - demolition

Internal elements	External elements
Dismount ramps	Fill in driving documentation
Lower stroke to reduce pressure on fastening screws	Attach documentation to the tool
Loosen tool	
Remove loose scrap	
Lift down tools to pallet with forklift	
Take tools to storage	
Cleaning	
Empty scrap	
Take away finished products	

Operator 1 - set up

Internal elements	External elements
Mount the coil	Prepare next order
Adjustment of support arm and width to coil	
Setting of the stroke machine	
Retrieve tool	
Clean tool	
Lubricate tool	
Upload tool with forklift	
Placement of tools by hand	
Fine tuning with help tools	
Tool tightening	
Checking of stroke length with a paper	
Removal of strap on coil	
Raise support table for feeder	
Led the coil to feeders by hand	
Roll out extra length of coil	
Place scrap box, output box	
Place ramp	
Feed coil to tool	
Adjust the position of the coil	
Feed the coil into the tool x cm	
A manual punching	
Visual inspection of punching	

Operator 1 - after a run

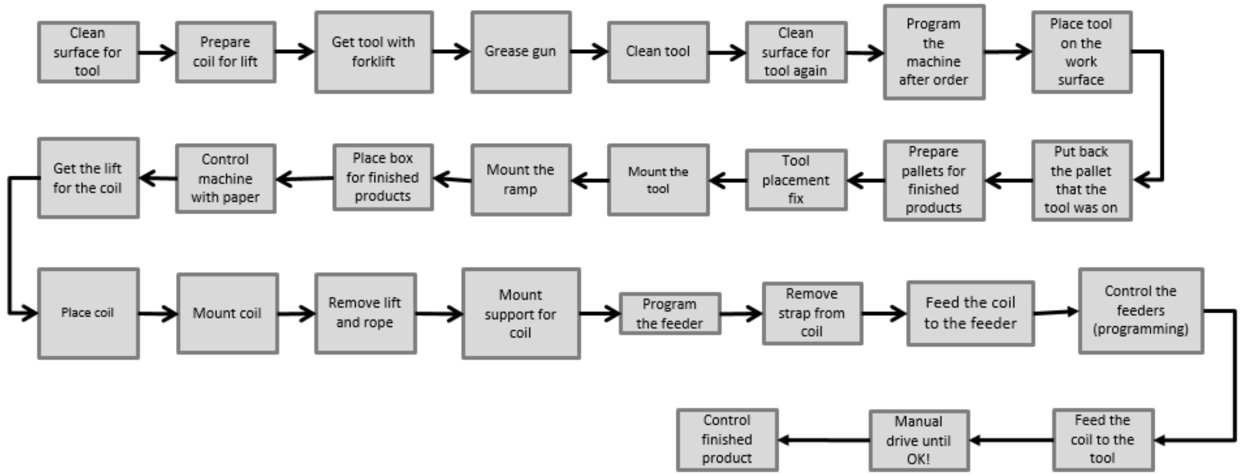
Internal elements	External elements
Move pallet to intermediate storage	Place new box
	Place full box on a separate pallet
	Check order / plan

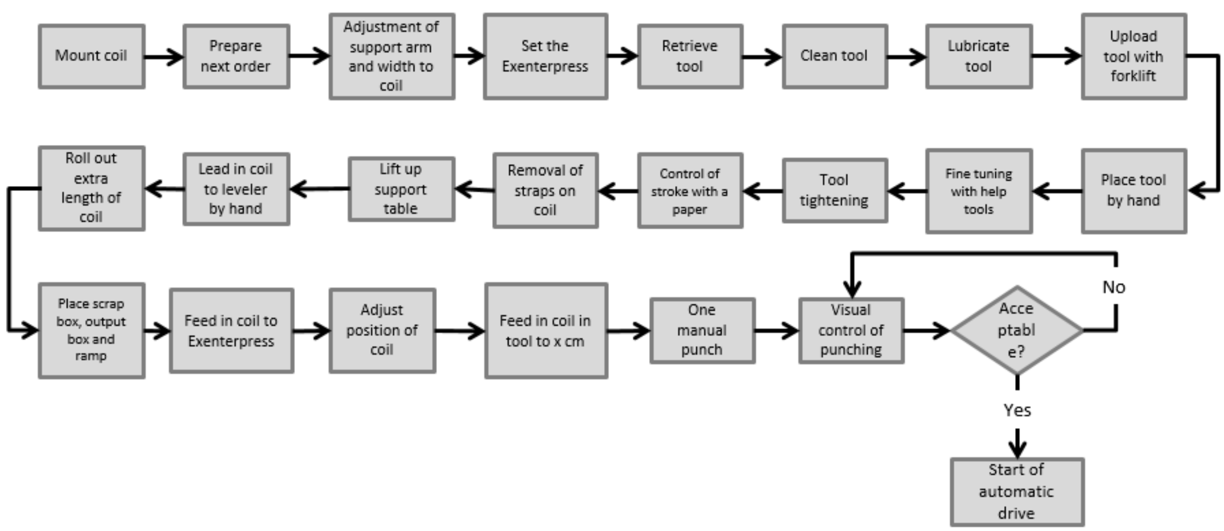
Operator 1 - planning

Internal elements	External elements
Prepare coil	Check order / planning
	Call for new coil
	Retrieve external ***

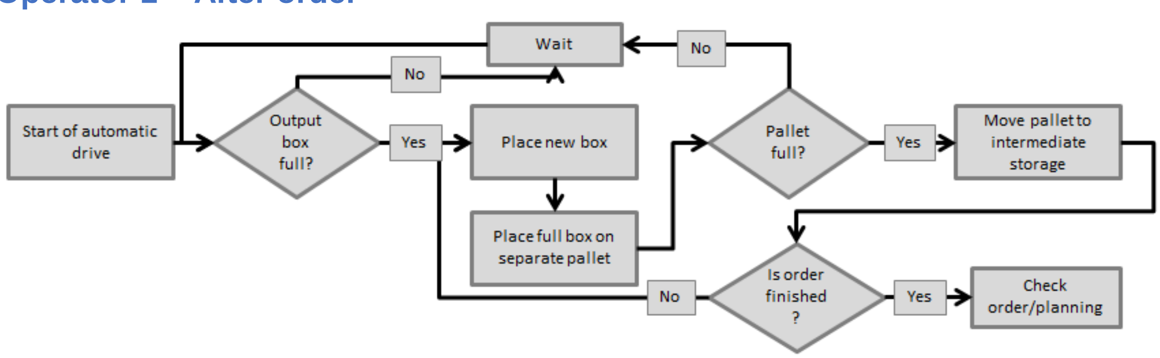
Appendix 3 – Flowcharts

Operator 1 – Mount of coil and tool

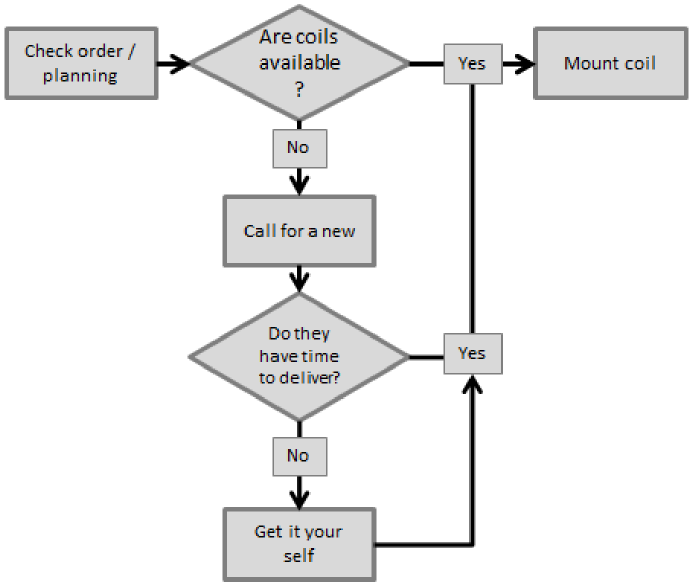




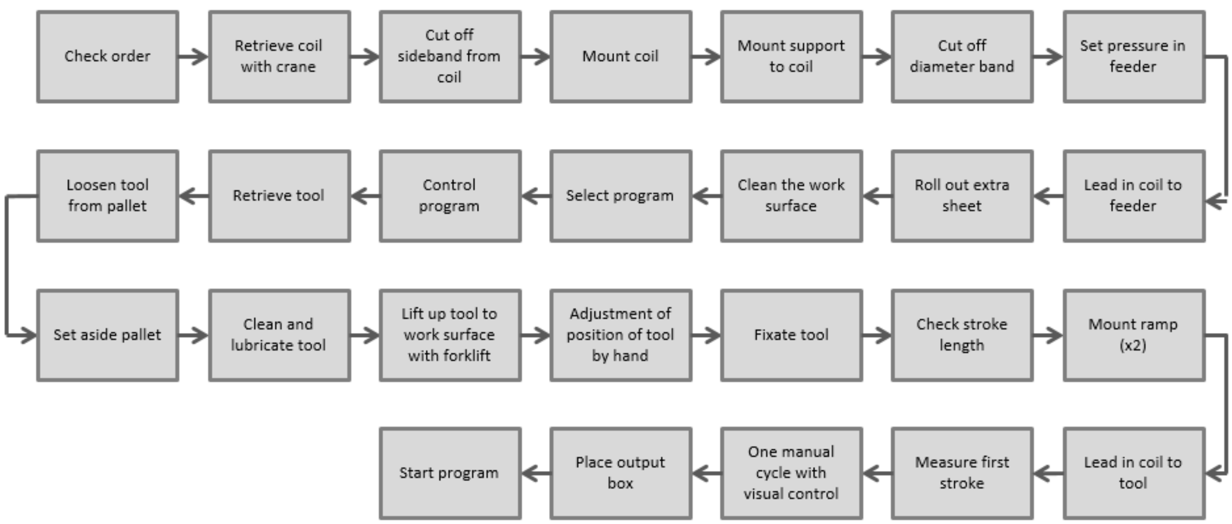
Operator 1 – After order



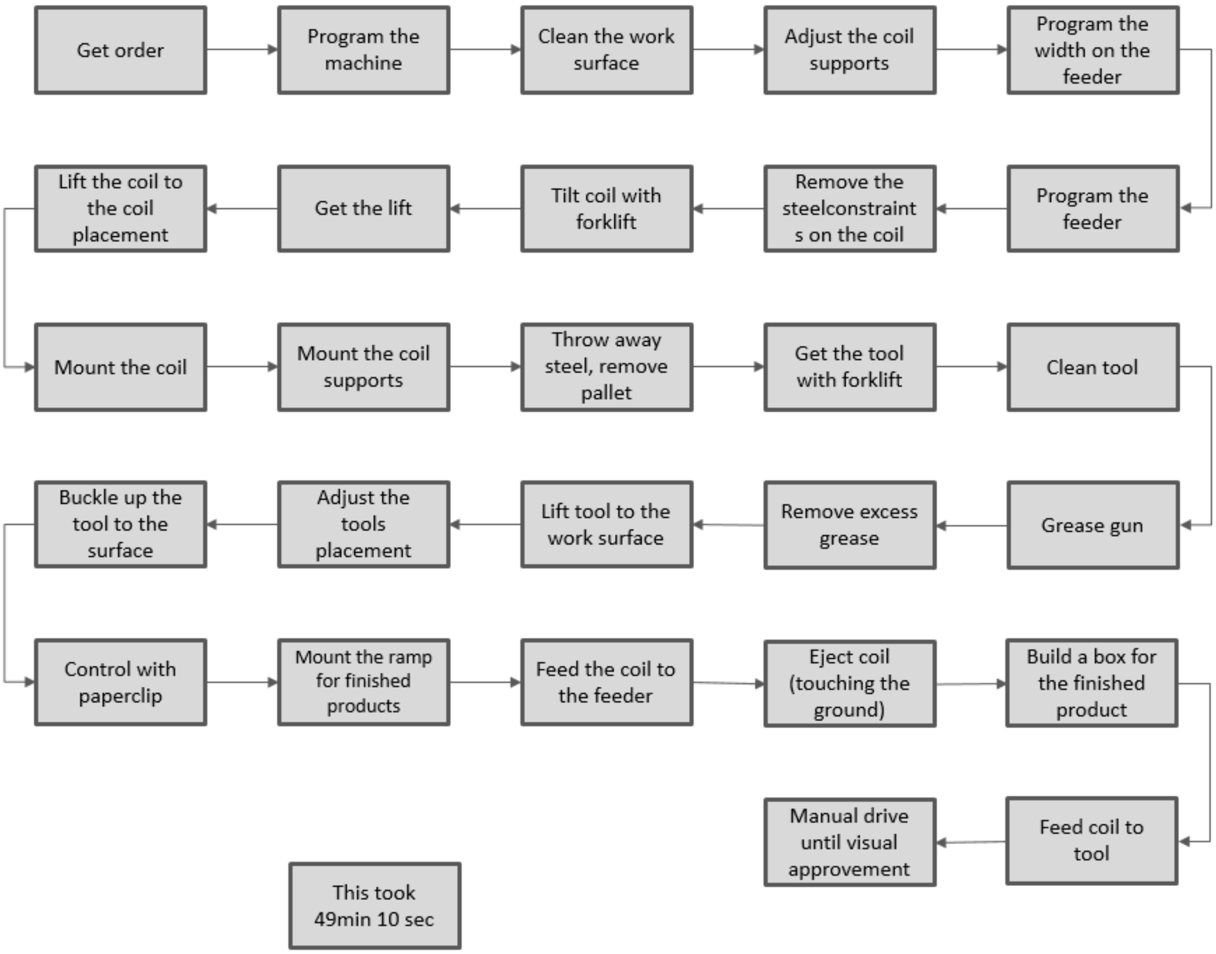
Operator 1 – Planning of order



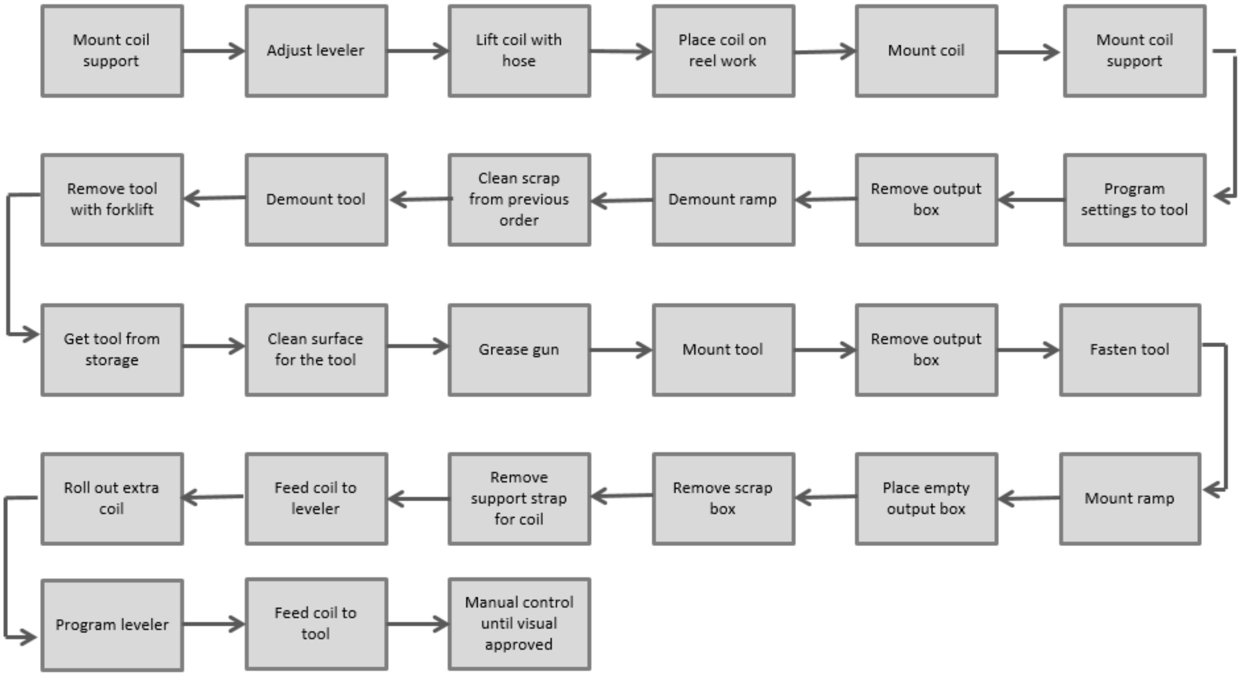
Operator 2 – Mount of coil and tool

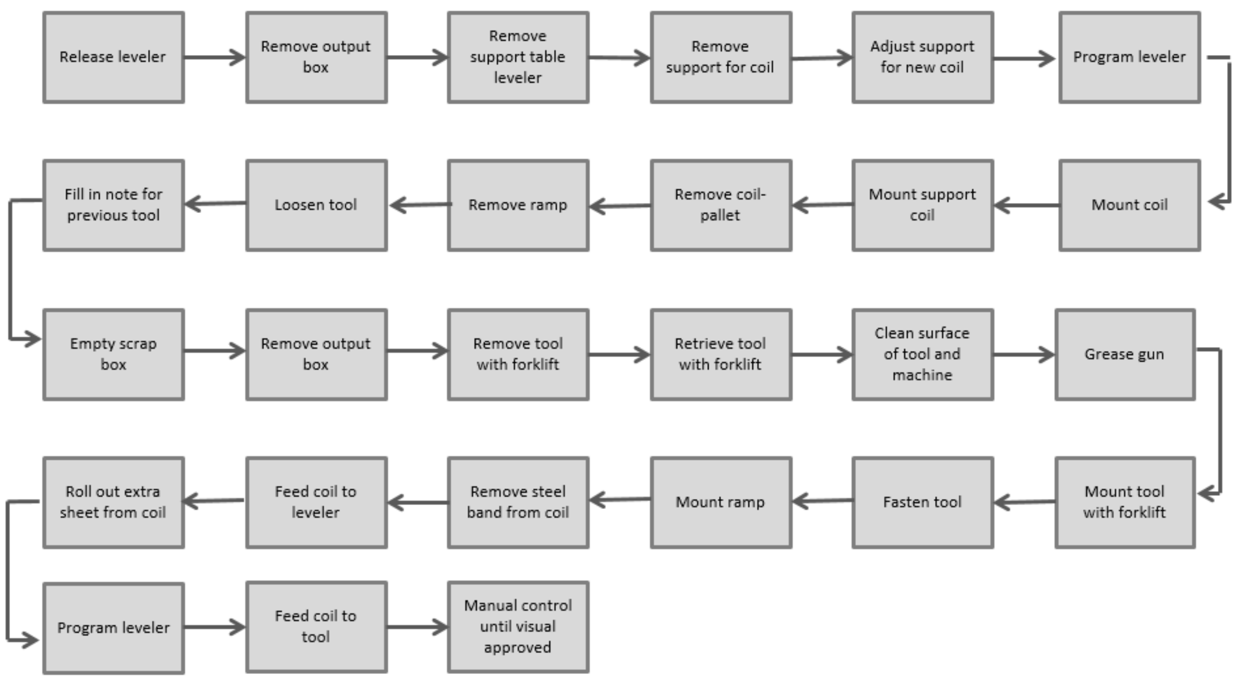


Operator 2 – Mount of coil and tool



Operator 2 – Demount and full changeover after implementing SMED





Appendix 4 - Instruction manual for Excenterpress
Planning

- Check orders for today's work shift
- Plan coils after order (If several orders use the same tool, run these in conjunction)
- Print all orders and put them in the correct order at the work station
- If no coils are available call xx-number

Setup

- Mount coil and support for coil
- Adjust feeder and support arm for coil (width)
- Set the correct program to the die press
- Control the program depending on the order
- Remove straps on the coil and remove support arm
- Set the feeder depending on the order
- Add coil to the feeder using support table
- Lower the support table and roll out extra sheet from the coil
- Mount tool with forklift
- Fasten tool and control stroke length
- Mount ramp, output box and if necessary scrap box
- Start the feeder and lead coil to the tool
- Measure length for coil depending on order
- Manually run the order until visually approved
- Start order

During the process

- Actions for the current order
    - If output box is full: Replace box with new and control sheet position in tool
    - Take away complete orders to the intermediate storage
    - Empty scrap box when necessary
        - Make sure to always have a scrap box placed
    - Fill in documentation of completed order and report in
    - Attach labels to the output boxes
    - Contact cleaning of tool if necessary
- Preparations
    - Clean and prepare tool for the next order
    - Prepare new coil if certain that the coil will run out
    - Prepare output boxes for finished products

Demolition

- Move output box to pallet
- Demount ramp and tool
- Take tool to storage
- Coil
    - If empty: Remove support
    - If not empty:
        - Remove width constraints, open feeder and roll back the coil

- Add strap
- Demount coil
- Take coil to storage

Appendix 5 – Measuring time

Before implementation of SMED

OP2 Changing of coil + tool, no demolition

Methodology

Took the time for mounting of the tool + coil and manual operation and visual control.

Start with settings → Mount support for coil * → Set the leveller * → Cuts of straps around coil * → Mount coil * → Lifts up with fork lift * → Runs to lift and raises coil to the reel parcel * → Returns lift → Mount support for coil → Cuts strap of coil → Support table (HERE IT HAS BEEN ABOUT 15 MIN), Feed coil to the leveller, roll out extra sheet from coil, throw away straps * → OP1 retrieves the tool * → Clean the machine → Sets the machine → Clean the tool * → Mount the tool (OP1 helps) → OP1 retrieves boxes for the products * → Mount ramp + pallets (HERE IT HAS BEEN ABOUT 28 MIN) → Set the tool with paper, clean the tool (ABOUT 30MIN), Feed coil to the tool, manually operates until visually approved, controls sample against template.

Total time 34 min 23 sec

OP1 Demolition and changing of tool, no coil switch

Methodology

Start by cutting off previous order where it has been punched → clean plate between leveler and tool → Demount ramp → Loosen all screws by the tool → Retrieve next tool → Clean tool on the way → Clean the workstation for the tool → Drew a line on the workbench for simpler mounting → Lubricated the tool on the way → Place tool on the worksurface → Attached the tool → Inputs the program → tested by clamping a piece of paper → Fed the sheet to the tool from the leveler → manual operation until visual OK.

12 min for demolition.
22.15 min for changeover.
Total time 34 min 30 sec.

Notes

OP1 waited for forklift ca 3 min in the middle of the changeover.
OP1 moved a pallet that was in the way of the tool that was to be used, ca 1min.
OP1 moved a forklift that was in the way of the tool that was to be used, ca 1min.
OP1 waited for help from OP2 to help tighten the tool (muscles), ca 3min.

OP2 Retrieve order, mount coil, mount tool, no demolition

Methodology

Refers to flowchart for OP2 slide 3.
In the middle of the changeover OP2 had to leave to help other two times. The first was about the automatic production line that had stopped and needed to be fixed (this took 6 min 22 sec), the second was about helping another operator at a separate machine (this took ca 2 min).

Preparation

During the run it was observed that assembling of output boxes was being conducted.
300 products per box, 48 products are made a minute, the order was for 3500 pieces.

When the box was full one product was controlled with a template and the finished box was placed on the side and a new box was placed at the machine.
To change a box took about 3 min 46 sec (where 2 minutes went to discuss something with OP1). The time was taken from the time the production line stopped until they resumed it again.
To fill an output box took about 6 min and 15 sec (this is the time the operators have to prepare the next order / help others)

Labels for the output boxes was retrieved and was stapled on.

During the third run OP2 had to go to another production hall to help one other production line that had stopped, this left our line empty.

After implementation of SMED

OP2 DEMOLITION + FULL CHANGEOVER

Full changeover + demolition took 47 min 35 sec.
Demolition: 16 min
Full changeover: 31 min 35 sec.

Notes

- Remove scrap took about 2 minutes
- Remove output box took about 4 min 20 sec
- If a table were installed, around 7 minutes could be removed from this changeover. (Get tool, clean tool, remove previous tool, prepare tool)
- A lot of pallets where in the way (bad layout, more space needed or clearer area for pallets)
- The forklift where in the way during the cleaning process of the tool, where in the way for another operators forklift)
- The coil pallet was removed during the changeover, this should be an external element.

If we compare to previous changeovers, the full changeover took 34 min 23 sec and demolition around 12 minutes. -> A total time of 46 min 23 sec.

OP2 DEMOLITION + FULL CHANGEOVER

Full changeover + demolition took 49 min 42 sek.

Notes

- Preparation of coil took about 7 minutes
- Remove scrap took about 2 minutes
- A lot of pallets where in the way (bad layout, more space needed or clearer area for pallets). This created a lot of problems: could not access the necessary equipment, had to hit some boxes and the shelf.

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