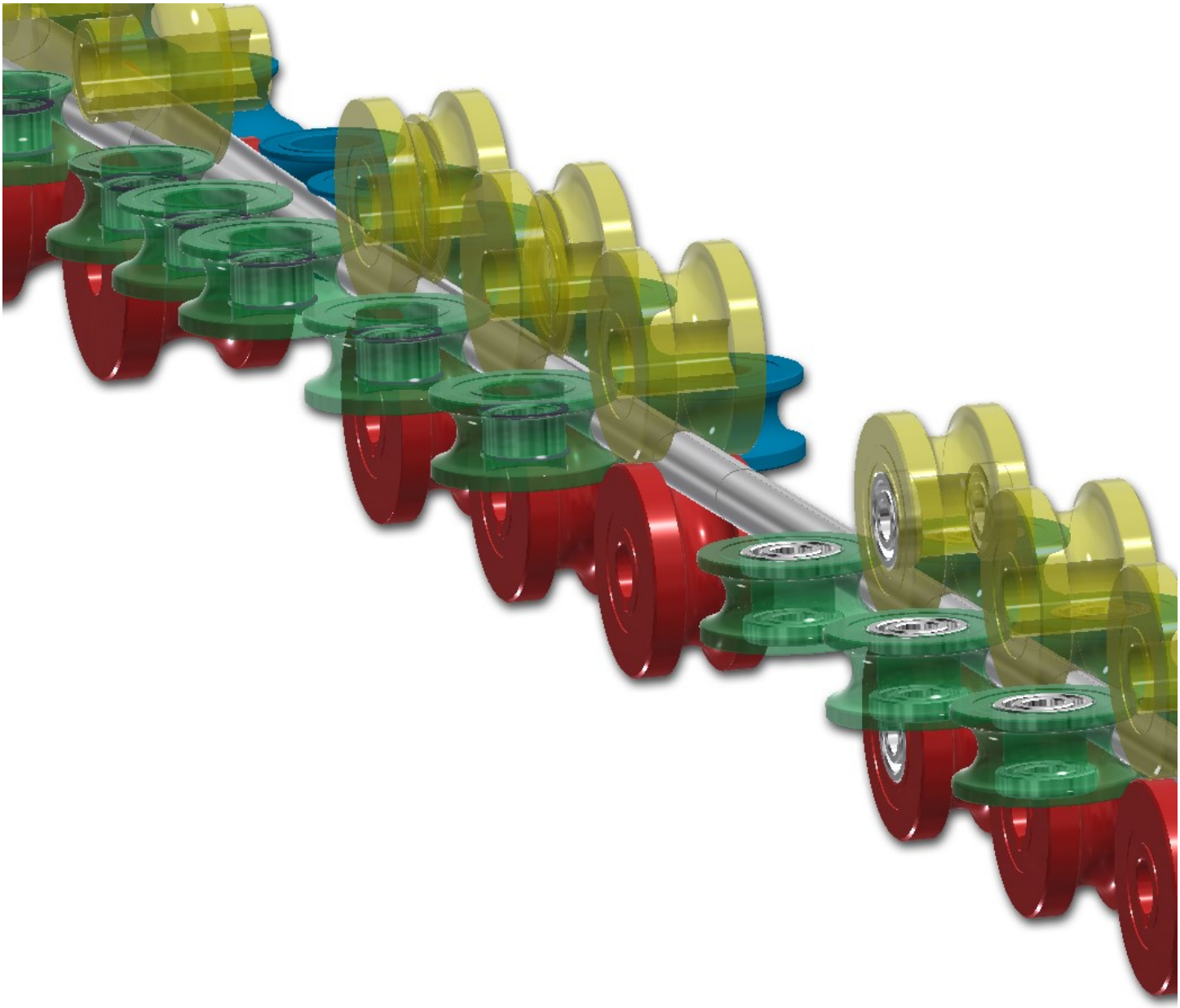

Improvement of the overall equipment effectiveness

Reducing the mechanical changeover time

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Industrial Engineering and Management

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i. Management Summary

Hadley group CRD Ede is a company that provides complex profiles to a wide variety of customers. The demand of the customers is growing which means that Hadley must increase their output. In order to do so Hadley is focussing on improving their Overall Equipment Effectiveness (OEE). This is a metric that measures how productive a company is. The OEE of last year was 33,8%, which means that 66,7% of the time is not used productively. One of the main reasons for this low OEE is caused by long changeovers. Therefore, this study aims to improve the OEE by reducing the changeover time of the mills in P3. To achieve this the following research question is answered:

How can the changeover time be reduced to improve the overall equipment effectiveness at Hadley?

For reducing the changeover time, interviews and the Single-Minute Exchange of Die (SMED) method are used. There are 5 interviews conducted with stakeholders that are important in the changeover process. These interviews are used to determine if the problems described are also seen during the observations. Besides that, the interviews are also used to find out if there are other problems that cannot directly be seen from the observations that causes problems with the changeover. The SMED method moves activities that happen when a machine is standing still to a moment when the machine is running. This reduces the amount of time that a machine is standing still. The SMED method uses observations to examine the activities during a mechanical changeover.

The biggest time losses in the current changeover process are spent on the "time spent away from the mill". Reasons for the setter to move away from the mill were because they were searching for tools, they were getting empty pallets from the repository, and they were talking with their colleagues when they were away from the mill. There are five solutions suggested for the changeover process. These solutions are based on the lean manufacturing theory. With the solutions there is attempted to streamline the process and to move activities to the external phase of the changeover process. The five solutions that are implemented are as follows:

Table 1: Overview of the solutions

Solution	Focuses on	Trade-off
Use the pallets of the new stands to bring the old stands to the repository.	Reducing the transportation time during the changeover	Employees need training on how to perform the new activity
Prepare the stands shortly before the changeover.	Reducing the transportation time during the changeover	It could be that the stands are in the way of other employees
Check if all the tools are present at the mill before the changeover starts	Reducing the time spent away from the mill	Extra time is spent on the preparation.
Print the drawings for the changeover before the changeover starts	Reducing the motions during the changeover	The company wants to have everything digital so this would be a step back
Perform the changeover with two persons instead of one	Reducing the time spent on the changeover	There are extra costs connected when an extra setter is used

It can be said that the changeover time is reduced by implementing all solutions except the solution that makes use of an extra setter. The solution “performing the changeover with two persons instead of one” was only performed partially since the setter was having a meeting and could only attend the second half of the changeover. Therefore, it cannot be concluded from this study that this solution had the desired effect on the changeover. The implementation of the solutions caused that the average changeover time was reduced with 56 minutes and 45 seconds. There is estimated that this reduction could increase the OEE from 33.8% to 34.6%. This is still not the desired 35% which is the company target. Besides the suggested solutions, recommendations are given based on the answers from the interview. These recommendations should help the company to reach their target of 35%.

Table 2: ***Overview of recommendation***

Recommendation	**Why?**
Define the start and end of the changeover process.	It becomes easier to track the time spent on a changeover. This visualizes where improvement is needed
Perform changeover in the same way	There is expected that the changeover process becomes more stable
Train more people to do some parts of the changeover	There will be more people that are able to perform some parts of the changeover. This could solve problems with the capacity
Create an urge to perform	There is no pressure for the setters to perform a changeover within a certain amount of time. So when a setter works 2 hours on a changeover that should take 1 hour no-one is complaining
Management and team leaders must start listening to the ideas of the setters	The setters are full of ideas on how to improve the changeover process. It is a waste when nothing is done with it
Start including the quality level of the OEE	The OEE is lower since the quality level is in reality not 100%. In order to find the problems related to quality this must be included
Apply 5s to the variables that are used for calculating the OEE	There are currently 54 variables present for the calculation of the OEE. Only 13 are actively used for calculating the OEE
Measure the accuracy of the feeler gauge	In the past there was resistance when using new ways of measuring. So the first step should be to measure the accuracy of the measurement tool. This could show the (in)accuracy of the feeler gauge

Contents

1 Introduction

This chapter describes Hadley Group CRD Ede, where the research is conducted. It explains the problems of the company and the research design. In the final part of this chapter, a brief description of the process is given. The aim of this chapter is to give background information about the company and the problem that needs to be solved.

1.1 Company Description

The research is conducted at Hadley Group. Hadley Group is a company that is specialized in complex roll-formed profiles. It was established in 1964 and has over 700 employees. Hadley has seven different locations around the world with the one in Ede being the European headquarter. There is a high variety of customers at Hadley coming from different industries. The customers are coming from the automotive, agriculture, retail, construction, lighting and solar energy industries. The high variety of customers causes a high product variety. The automotive industry has a very high priority at Hadley. There are strict rules about the quality of the profiles and about when the profiles need to be delivered. When Hadley is not meeting the quality standards or is delivering parts too late, they will receive a huge fine.

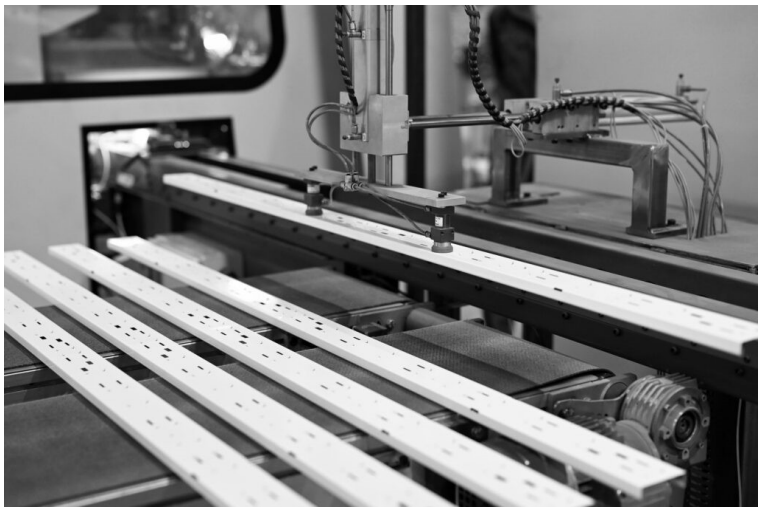


Figure 1: ***Example of a profile that is produced***

Roll forming is a process where a metal sheet gets bent when it goes through multiple stands. Each stand will bend the sheet a little bit to get the desired profile. The process is ideal for producing profiles in large quantities, because it guarantees a certain consistency in the process, the process is environmentally friendly, a large variety of profile structures can be made, and it can be used for multiple types of metal. Besides roll-forming, other inline operations are available if a profile needs additional details. Some examples of inline operations that Hadley provides are punching holes, attaching protective foil and welding the profile together. Door frames, frames where solar panels are attached to and frames for the roof of the car are examples of products that are made with this process. These inline operations are used based on the customer needs.

1.2 Problem Description

During the corona pandemic, a lot of employees had to get into quarantine which led to a postponement of the work at Hadley. Besides corona, the demand from the solar-energy industry increased which combined led to an increase in the lead time from 6 to 26 weeks. The company is creating a strategic plan for the coming 5 years where they want to be more profitable. One of the things that is part of this plan is to improve the operational effectiveness of the company. To

measure the effectiveness of the company Hadley is using the Overall Equipment Effectiveness (OEE) as Key Performance Indicator (KPI). The OEE evaluates how effective an operation is utilizing its equipment. For calculating the OEE three rates are multiplied with each other. These rates are the availability rate, performance rate and quality rate (Theisens, 2017). Figure 2 shows an overview of how the OEE is calculated. In the top of the figure there is the total operating time. This is the total time that is available within the time span. If you would measure the OEE over a day the total operating time would be 24 hours. Unscheduled time is the time that is deliberately not scheduled to perform for example preventive maintenance or to test the equipment.

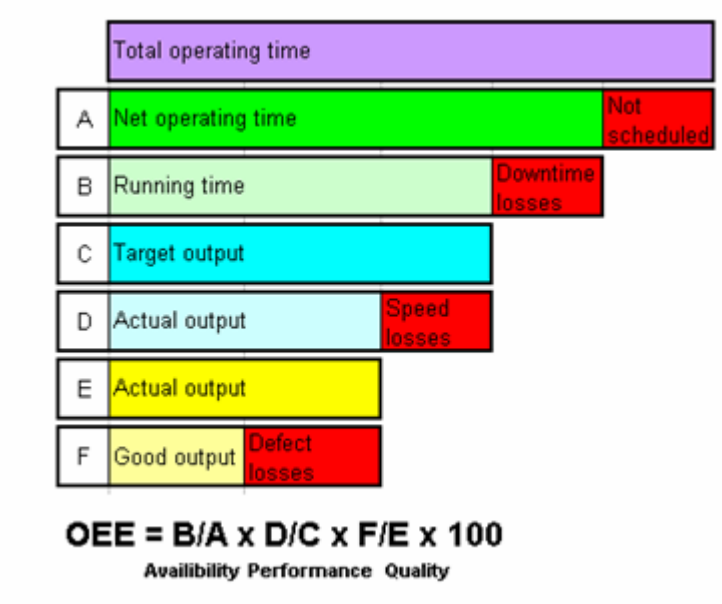


Figure 2: ***Overview of the OEE***

Availability rate

The remaining time after deducting the unscheduled time from the total operating time is the net operating time, which could also be defined as the scheduled production time. During the scheduled production time there can be moments when the machine is not running. This is called the downtime and is caused by for example, changeovers, coffee breaks or machine malfunctions. When the running time is subtracted from the net operating time the running time remains. The availability rate is defined as the percentage of time that the machine is running within the scheduled production time.

Performance rate

The performance rate is the percentage of actual output in relation to the target output. One can calculate what the target output should be for the running time by looking at how much time it takes to produce one product and the running time of the machine. In reality the machines will not always run at the highest speed and minor breaks occur to inspect the machine or to get some coffee for instance. Activities that prevent the machines from running at their maximum speed are called speed losses. The actual output is the output that remains when the speed losses are subtracted from the target output.

Quality rate

Within the actual output there are losses as well, called defect losses. These losses are products that are containing malfunctions or other errors. The quality rate is determined by dividing the output

that is produced right by the actual output. Therefore a quality rate of 95% means that 95% of the products is produced right in the first time.

The target OEE at Hadley is currently 35% for all the mills. On average an OEE of 30% is achieved. The discrepancy is 5% between the norm and what is really achieved. For calculating the OEE, Hadley is using an OEE toolkit that measures the variables and does the calculations to calculate the OEE.

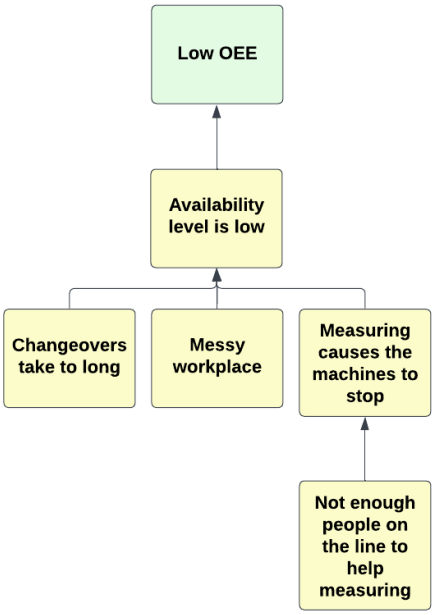


Figure 3: ***Part of the problem cluster that is concerned with the availability level***

Figure 3 shows a part of the problem cluster related to the availability rate. The complete problem cluster can be found in appendix 11.1. In the complete problem cluster there are three other categories that are related to the low OEE.

At Hadley, the machines are set at a performance rate of 75%. This is done to guarantee a stable process in the beginning of the production. The material properties of the raw material differ a lot during production. Therefore a lower speed of the machines is used to create a stable process. Another reason for a lower performance level is that some machines are using a cutting tool which makes the machine stop for 2 to 3 seconds. These stoppages are seen as minor stoppages and are also categorized under the performance rate.

A fixed value of 100% is used for the quality level. In reality, the quality level is lower. The company measured in the year 2022 a scrap level of 5%. Which means that 5% of the material is wasted during production. A test production run is used to see if the production process of the product is stable enough after a changeover. This production run takes twenty minutes and if the production run is not stable enough the products are thrown away. Besides that, during production runs there are standing carts next to the machines with profiles that did not came through the measurement tests. Both of these examples are already indicating that the quality level is in reality not 100% but lower. Therefore, the OEE is probably lower as well.

The biggest problem of the OEE is linked to the availability level. Unscheduled maintenance, changeovers, measuring and idle times are examples of moments when the machine is standing still and thus not producing. From figure 17 (see Appendix B), it can be seen that last year the changeover time took 15% of the total operating time. Besides production, this is the activity that took the most

amount of time. The average changeover time per week in 2022 is currently 113 hours. This is not for a single mill, but for all the mills combined. Since the changeover time is the activity with the longest duration after production, there is expected that the biggest impact on the OEE is made by reducing the changeover times. According to Heerkens and van Winden (2017), a problem with the greatest impact and with the lowest expected costs one should chose to solve. Since the changeover time is demanding most of the downtime of the mills there is expected to make the biggest impact in this area. This also means that it is important to consider the possible costs that are included with possible solutions

1.3 Process

This section gives an overview of the general production process and the changeover process. It also provides the different steps that are performed and explanation to get a better understanding of the machine and what is changed during the changeover process.

1.3.1 Production Process

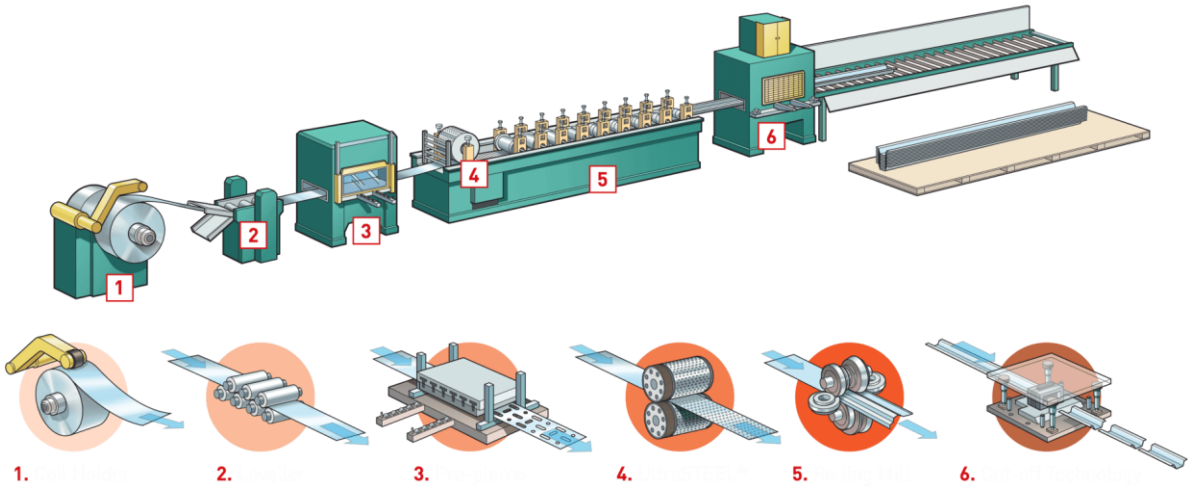


Figure 4: *Overview of the tools that can be used on a mill. (Source: https://www.hadleygroup.com/custom-roll-forming/custom-capabilities/cold-roll-forming/)*

Figure 4 shows an image of the different materials and tools that can be used on a mill. There are a few steps that can happen before the profile is formed in the right way. The first image shows a coil of metal that is pulled through the machine. This is the raw material that will be used to produce a profile. Figure 4 also shows on the other side of the coil holder that there is space for another coil. These coils are put there in advance to reduce the time of getting new material ready. The second image shows the leveller. Which is a tool that makes sure the sheet of metal enters the mill horizontally. After passing the leveller, the metal can be punched by the punching machine. Not every profile needs to be punched but for a lot of profiles this will be the case. The punching happens most often before the profile is formed to prevent any deformations. But there is also the option to punch the profile after the forming. The fourth stage does not happen at Hadley in Ede. The process that does happen in advance is a roll that sprays a certain type of oil on the metal to make it easier to form the metal in the roll forming process.

In the fifth step the metal gets bent into a profile. This bending happens on multiple stands that are placed behind each other (See figure 18 in appendix D). Each stand bends the metal a little bit to eventually create the desired profile. The amount of stands that is used for a profile varies per profile. Most of the time it varies between 6 to 30 stands depending on the complexity of the profile. Between the fifth and the sixth step there is also the possibility to weld the profile together. This process is used to create a closed profile. In the final step of the process the profile is cut in the desired length. In most of the processes, this step is automated by an automatic cutting machine which cuts the profile to the desired length. The finished profile is put on to trays or put into boxes and is collected by forklifts which will put the boxes or trays in the repository.

There are seventeen mills on the production floor that are divided in multiple areas. The areas are called P1, P2, P3, P4 and Hal Oost. P2 and P3 are the most important areas since they are containing

fourteen mills that are available. P2 consists out of five mills which are using stands that are lighter and overall less complex compared to the stands in P3. P3 consist out of nine mills and focuses on profiles that are more complex than the profiles that are produced in P2. For an overview of the production floor see appendix 11.5.

1.3.2 Changeover process

When a new profile needs to be produced, a production line will be changed over into a new production line. This process is called the changeover process and happens in five phases. The first and the last phases are happening while the machine is still producing. and the other three are happening while the machine is not producing. Figure 5 gives an overview of the steps that are involved in the changeover process. The green boxes are processes that happen when the machine is producing products and the red boxes are processes that are performed when the production is standing still.

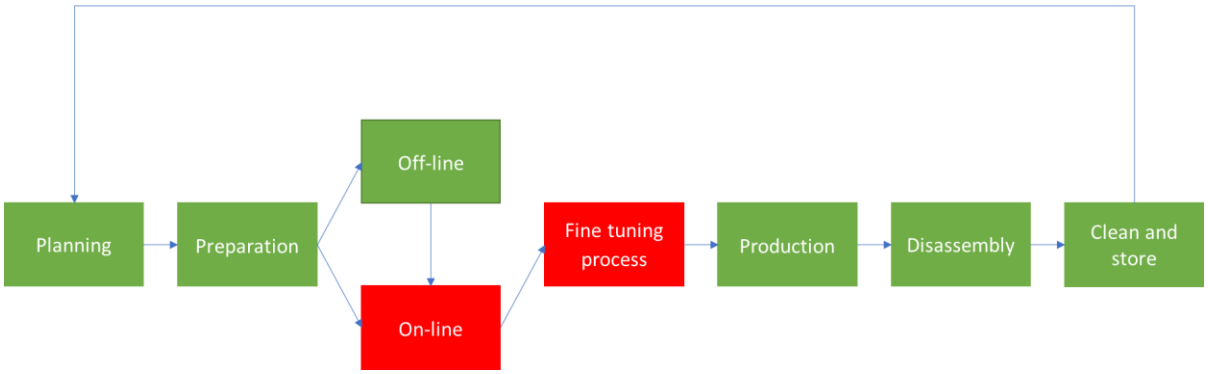


Figure 5: ***Simplified overview of the current changeover process***

Preparation

In the first phase the stands are assembled before they are put on the mill. The rollers that are used for the stands are stored on the production floor in a repository. The person that is in control of the repository will prepare get the rollers from a lift and prepares them in the right order for the setter. Approximately a week before the changeover a setter will start working on assembling the stands for the changeover. The idea is that the stands are prepared before the production ends so that the changeover can start right away.

Mechanical changeover

When the production ends the mill is prepared by the operator or the setter for the mechanical changeover. The final profiles are produced and if there is some material left this is pulled out of the rollers. After everything is prepared the mechanical changeover really starts. The mechanical changeover process is the process where the old stands are going of the mill and the new stands are put onto the mill. It sometimes happens that a setter is not ready with the assembly of the stands before the production ends. This means that the setter needs to assemble the stands on-line. During an on-line changeover, the stands are assembled on the mill. This causes that the duration of the downtime increases because, instead of changing the old stands with the new stands, the old stands first need to be disassembled and after that the new stands are assembled. Reasons for on-line changeovers are sudden orders that have more priority than the scheduled order. An off-line changeover is a changeover when everything is prepared on time. The off-line and on-line changeovers are both mechanical changeovers.

The company mechanic is switching the press and the cutting machine during the mechanical changeover. The type of press or cutting machine could be dependent on the profile. After the cutting machine and press are in place the company mechanic will apply the right settings. For the press it is important that the holes are made in the right sequence and at the right place. And for the cutting machine it is important that the profile is cut at the right length.

Fine tuning

After the mechanical changeover the fine tuning process starts. The metal sheet gets pulled through all the stands for the first time. Checks are done to see if the material will actually go through the stands and if the properties of the profile are within the given limits of the first measurement. When the profile is within the desired limits, it is send to the quality department. The quality department is looking and feeling the profile for irregularities. There is also looked if the dimensions of the profile are within the limits. f the profile is not within the desired limits, the setter needs to adjust the stands to get the profile within the limits. Adjusting the stands is a very precise task since the rollers are moving up or down and from left to right by a few tenths or hundredths of a millimetre.

Production

When the quality department agrees that the product is good, a test production run is started to see if the material behaves well during production. When this is not the case the setter and the company mechanic will both work on the production line to keep the profile within the margins during the test run. If everything is finally within specifications and production is at the right speed the actual production is started and the old stands are disassembled. After the rollers are disassembled they are sent to the repository where they are cleaned. When the rollers are clean they are stored in the repository. It could be that the stands are not disassembled. When it is very difficult to prepare the stands, the stands are lifted from the machine and put in the repository.

Figure 6: ***Picture of 2 cassettes on a kart***

There are two different types of mills in P3 that are using a different setup for the stands. The first type makes use of so called cassettes. This is basically a plateau where most of the time three stands are attached to with the use of bolts, see figure 6 for clarity. Before the production ends the cassettes with the stands are prepared and ready at the machine. In order to get the cassettes to the

mill they are put on a kart with room for two cassettes. A crane is used to lift the cassettes from the kart onto the mill.

The other type of changeover is not making use of cassettes. Stands are prepared on a pallet and put in the shelves. Figure 7 shows how the stands are placed on a pallet. Once the changeover starts the old stands are detached from the mill and put on an empty pallet. This pallet can lift up to 7 stands and once the pallet is full it is put back in the shelves. This process is done over and over until all the stands are from the mill. Once the stands are from the mill, the mill is cleaned before it can be used again. The new stands are brought from the repository to the mill and pushed by hand on the mill. Once all stands are from the pallet the empty pallet is stored in the repository and the new stands are brought to the mill. This process is done over and over until all the stands are ready on the mill.

Figure 7: ***Picture of stands on a pallet.***

1.4 Research Approach

This section covers the research question and the aim of the research. The research question aims to find an answer on how to increase the OEE by a reduction in the changeover time. There are sub-questions formed that help answering the research question.

How can the changeover time be reduced to improve the overall equipment effectiveness at Hadley?

The current target for the OEE is set by the company on 35% There is not a target for the changeover time. However, the company estimated that the total changeover process should take approximately eight hours. In order to get an answer to the research question, the following sub-questions are formulated:

What are the bottlenecks in the changeover process?

An important step in improving the OEE is to find the bottlenecks in the current process. The OEE covers multiple processes, so it is important to find the most important problems in the current

process otherwise a lot of time can be wasted. A reduction in the changeover time can lead to an increase in the availability level. This increase will lead to an improvement of the OEE if the other two variables remain the same.

Which solution(s) will improve the changeover process?

The aim of the solutions that are implemented is to reduce the changeover time. It could be that the solutions do not have the desired effect on the changeover time. Therefore, it is important to look at the aim of the solution and if the desired result is achieved after implementation. A solution is considered effective if the goal of the solution is achieved.

The aim of this research is to provide the company solutions to reduce the changeover time. The following chapter is about the current production and changeover process. Besides that, the chapter also contains literature about Single-Minute Exchange of Die, Lean Manufacturing and Quick Response Management. Observations and interviews are used to reduce the changeover time. From the observations it should become clear what the activities are the cost the most amount of time. The interviews are used to find out what the causes are of the problems and to see if there are other problems that cannot be deducted from the observations. Possible solutions that can reduce the changeover time in the short term are implemented and the effect of the solutions are analysed. Finally, there will be looked at if the solutions had the desired effect and what the company must do in the future to reduce the changeover time.

2 Literature Review

This section consists of the theories that are used for the research. The theories are all based on the Lean manufacturing strategy. The purpose of this chapter is to get a better understanding of the current production and changeover process. Besides understanding the current situation this chapter also gives theories that are used for solving the problem.

2.1 Single-Minute Exchange of Die

Single-Minute Exchange of Die (SMED) is focussing on reducing the changeover times on a machine. This is done by mapping the various performed activities and trying to move the internal activities to external activities. Internal activities are activities that are performed while the machine is idle and external activities are activities related to the changeover that happen while the machine is producing. Besides switching internal activities to external activities, SMED also looks at streamlining the activities after internal activities are moved. (Sundar et al, 2014). Currently, there are still a lot of activities that are happening internally which means that there is a lot of time wasted with the machine standing still.

The SMED method focusses on reducing waste in the manufacturing process. It is one of the lean manufacturing methods that gives a quick and efficient way to change the production process from producing one product to another product. The reduction of the changeover time reduces the lot sizes and improves the flow of the process (Ulutas, 2011).

According to Shingo (1985) the SMED method has three stages. In the first stage internal and external steps are separated from each other. The aim is to ensure that activities that can be performed as an external activity are actually performed when the machine is running. One of the things that can help is the use of a checklist. Following the list will make sure that there is nothing missing during the changeover. When this is done before the start of the changeover, a lot of errors can be prevented. In the second stage are some of the internal steps converted into external steps. One can achieve this by preparing the changeover conditions beforehand. To make it clear what this is meaning, an example by Shingo (1985) is used. In this example dies are cold when attached to a machine. In order to heat up the die, molten metal is injected as a trial run. The material injected during the heating process produces errors in the castings. One way to solve this is to preheat the dies with gas or electric wires beforehand. In the final stage of the SMED method, all steps in the changeover process are streamlined. For the external activities this could be for example improving the transportation and storage of parts and tools. For the internal process this could be the help from a second setter that helps during the first part of the changeover.

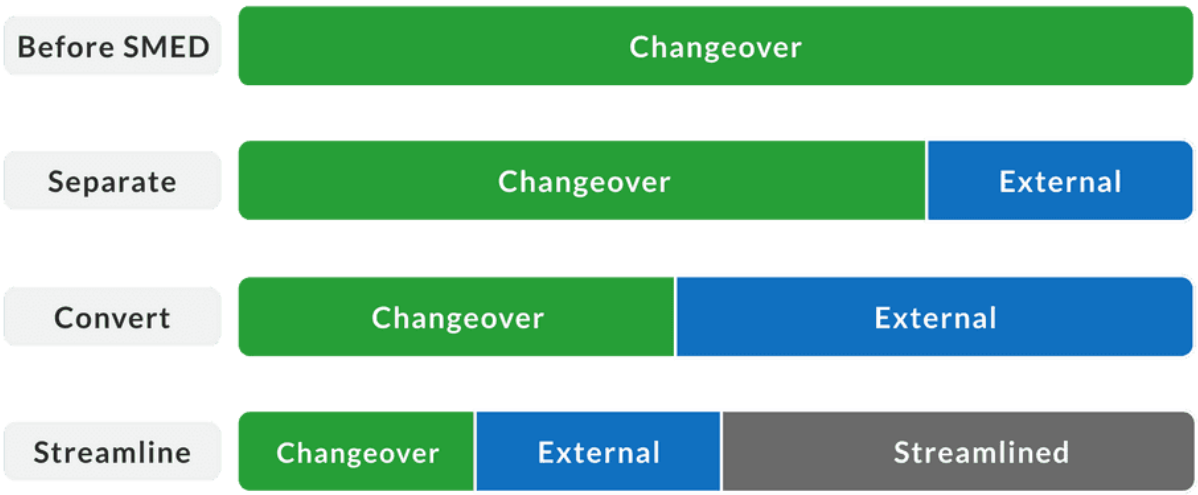


Figure 8: *Overview of a changeover process before- and after a SMED analysis (Source: https://www.leanproduction.com/smed/)*

There are multiple effects that can be achieved by implementing SMED (Shingo, 1985). With the use of SMED, inventories within the company are reduced to a minimum, productivity rises since there are less stock handling operations and a reduction in the changeover time made the company more flexible since it was able to mix up the production more often. Shingo analysed the average changeover time of forty one companies over ten years that were using the SMED method. The results were that the average changeover time was reduced to one-fortieth of the time that it originally took.

A few years ago Hadley already started with the implementation improvements that are focussed on the changeover process. There is no information about the specific duration of the changeover before the improvements. There is assumed that changeover process before improvements had a duration of 12 hours, based on the improvements that are implemented. This would mean that the use of SMED could potentially reduce the changeover time to 12-30 minutes. Another important effect that can be expected is that stock reductions lead to a more efficient use of the plant space. An inventory reduction at Citroen caused that a planned construction of a new building was stopped because the extra space was not needed anymore. Hadley is currently having problems with the inventory as well and therefore this could be interesting to look at.

2.2 Lean Manufacturing

Lean management is an approach which contains multiple management practices that can work synergistically to create a process that is without waste and of high quality (Shah & Ward, 2003). Examples of other practices that will be used are Quick Response Management (QRM), SMED and 5s. With lean manufacturing, the goal is to respond to the demand of the customer. The main way to do this is to remove the “waste” within a process. The goal of lean manufacturing is to produce products for the customer at the lowest costs and as fast as needed (Bhamu & Singh Sangwan, n.d.).

Lean manufacturing is trying to produce products using less of everything. This method will improve the customer satisfaction by focussing on removing wastes. Waste in a process is any activity that does not brings the processes closer to the final output or adds value to the final process (Wang, 2010). During the implementation of SMED there will also be looked at if there are activities happening that cause a lot of waste. There will be looked at how these wastes can be reduced or completely removed from the changeover process. But simply including lean manufacturing in the company will not always convert into benefits. Doolen and Hacker (2005) explain that there are

factors like changing economics, high levels of demand uncertainty, rigid organizational structures and high variety-low volume product portfolios that can prevent manufacturers from enjoying the benefits of lean. The lean method describes three categories that are seen as waste which can be found within a company. These are Muda (waste), Mura (inconsistency), Muri (overburden). The improvements of the changeover process will be based on these concepts (Theisens, 2017)

2.2.1 MUDA, MURA, MURI

Muda, Mura and Muri are activities or things that are disturbing the process. Muda means waste and focuses on reducing non value adding activities. Mura is unevenness, removing the unevenness in the process will improve predictability. Muri is the overburden, bad ergonomics and delaying preventive maintenance are examples of overburden (Theisens, 2017). Muda refers to the activities in a process that does not add value to the product for the company or customer. Reducing Muda can be achieved by not using more equipment than needed. There are eight types of wastes that exists within a company which are described in figure 9

Figure 9: ***Eight types of wastes (Source: https://theleanway.net/The-8-Wastes-of-Lean)***

Mura is about a lack of consistency in a process. A high variety in the process makes it hard to predict what the outcome will be. To reduce Mura a step could be to even the workload over multiple stations. This will reduce inventory on the production floor. It is necessary to develop a forecasting system in order to avoid shortages or late deliveries of parts.

Finally, Muri is about the overburden of machines and humans. Bad ergonomics and postponing preventive maintenance are examples of overburden that can occur. To reduce Muri in a company it is important to standardize and simplify processes. There are a few things that are needed to standardize the process. Standardization has multiple benefits. The process becomes more clear and predictable, it will be easier to perform the process, If everyone performs the process in the same way the output becomes more consistent as well and finally it reduces the waste in a process.

2.2.2 5s method

The 5s technique is trying to create a smart work environment. 5s is a tool used within lean management and it gets rid of the wastes and most importantly, prevents it from reoccurring in the future. The 5s stand for Sort, Straighten, Shine, Standardize and Sustain. They represent the steps that need to be taken to reduce the waste in the workspace. (Theisens, 2017)

Sort: in the first step there is going to be looked at the necessary and the unnecessary things in the workspace. Only items that are used regularly are present. Unnecessary items are removed or moved to another location. Besides throwing away or moving unnecessary, broken equipment or items should be fixed as well.

Straighten: After making the workplace clean there is going to be looked at giving each item a permanent location. It should be easy for everyone to find what they need to use. After use, it needs to be clear where to put the items back.

Shine: The objective of the third step is not to make everything clean and organized but to keep it that way. Everything must be kept clean since it is easier to find out where problems are in a clean work environment.

Standardize: there should be rules and standards for how certain work practices are performed. It must be clear what should be done to keep the workplace clean and safe.

Sustain: The last step is about sustaining the steps that are taken. This means that for example management has to make sure that every step is being followed. Controlling every day isn't necessary but checking once a week if the workstations are clean is something that could be done.

2.3 Quick Response Manufacturing

In the late 1980s a strategy with the name Time-Based Competition (TBC) was created. TBC used speed to get a competitive advantage. TBC is the predecessor of Quick Response Manufacturing (QRM). QRM is an approach that is used internally to minimize the lead times for the whole company. It focuses on both the production floor and the office (Tubino & Suri, 2000). The external aspect of QRM focuses on the customer and the market. QRM is trying to provide the customer in two special needs. It aims to speed up the design and manufacturing process of a product according to the wishes of the customer (Suri, 2010).

Manufacturing Critical-path Time (MCT) is used to measure the effectivity of the QRM strategy. The MCT Is the time from the order customer until the first product delivery. MCT is used to highlight the opportunities to improve the company by examining the processes that are needed to get the product or service to the customer. Reducing the MCT can lead to improvements in the quality of the products, reduction of the costs, improvement of the on-time delivery and an increase in the profits (Suri, 2014).

According to Suri (2010) there are four important changes that are needed when implementing QRM. These are:
From functional to cellular, this means that the company should no longer work with departments that are specialised to do a certain task. Instead start working in so called QRM cells. These cells are containing employees that are flexible to perform multiple tasks. The sources that are needed for this cell can only be used by the employees that are working in this cell.
From top-down to team ownership, Instead of that the managers and team leaders are telling what the employees need to do, the teams will decide for their QRM cell what needs to be done to reduce the MCT. The people in the QRM cell are completely accountable for the operations in the cell. The manager will only give the QRM cell the limits in how far they can go in certain decisions.
From specialised workers to flexible workers, It is also important that companies start focusing on cross-training. This means that employees are getting knowledge about all the operations that can occur within a QRM cell. The flexibility of the company will increase when employees can be deployed on multiple tasks if this is needed for an order. The capacity of the employees is shifted to the processes that needs it at that specific moment.

From efficiency to MCT reduction, when the productivity of a machine is the performance indicator of an operator, the operator is only focussed on running the machine and producing as much as possible. The MCT is focussing on reducing the time from customer order to the first product delivery. When this becomes the performance indicator for the operator, the operator will not only focus on the productivity, but also the other aspects that are needed to deliver the product on time.

The aim of this report is to increase the OEE by reducing the changeover times. In order to achieve this it is important to find out what the bottlenecks are in the changeover process. To find out what the bottlenecks are the SMED method is used. The SMED method gains insight into the activities that are happening during a changeover. The theory of lean manufacturing is used to come up with solutions for the problems that are discovered with SMED. QRM and the lean manufacturing method are both used for the recommendations that are written based on the results.

3 Methodology

This chapter explains the methods that are used within this research to reduce the changeover time. The methodology consists out of interviews and the SMED method. This chapter gives an explanation about how the research is conducted and about why certain choices are made.

For this study the SMED method is used to reduce the changeover time. The internal phase of the changeover process at Hadley takes 15% of the net. operating time, as explained in section 1.2. Since the focus of SMED is to reduce the time spent on the internal phase of the changeover process there is decided to use SMED. The SMED method focusses on how to reduce the changeover time by moving activities from the internal phase to the external phase. For the SMED method quantitative observations are used. There is looked at the activities that happen during the changeover and how long these activities are happening. The reason for using quantitative observations is that the study is easy to replicate and that the results can be compared statistically.

The thesis consists of an explanatory study. According to Cooper and Schindler (2014), an explanatory study tries not only to describe the problem that occurs, but it is also trying to explain why the problem occurred in the first place. The reason for conducting the interviews is to understand the cause of the problems that are encountered during the observations. In the past there is tried to improve the changeover process, but these improvements did not hold or only partially. Therefore it is important to understand why these improvements are not working.

3.1 Interviews

Interviews are performed with employees involved in the changeover process. The goal of the interviews was to find the causes of the problems and to see if there are problems that cannot be observed during the observations. Besides that, the interviews were used to see if the problems that are described by the employees on the production floor are also the problems described by the managers or team leaders. Table 3 shows an overview of the employees that are interviewed and why they are included. There were five setters interviewed in order to improve the external validity. Besides that, the interviews for the setters and the company mechanic were all performed at the production floor and the interviews for the managers and the team leader were performed in their office room. After the interview the person who was interviewed received the text that was used for this report in order to confirm that what is noted is true.

The interviews that are conducted are semi structured. This means that there are questions prepared before the interview started. A semi structured interview gives the moderator the chance to get a higher variety of answers compared to structured research where the questions are determined before the interview. Besides that, a semi structured interview can give more clarity of answers because the moderator is allowed to ask follow up questions. Another form of interview is the unstructured interview where there are no questions prepared in advance. Since the changeover process will be the topic of the interviews there is decided not to use unstructured interviews since this can lead to talking about topics that are irrelevant for the research. To have some form of structure during the interview with the possibility to ask follow up questions it has been decided to use semi structured interviews (Cooper& Schindler, 2014) (See Appendix F for the interview structure). There are five interviews performed that took between 30 and 60 minutes.

Table 3: *Interviewees*

Who?	Why?
Setter	Are the persons that are directly working on the changeovers. Possible improvements are discussed with these people since they are the ones working on it.
Company Mechanic	Is for example preparing the punching and cutting machine during changeover. When the preparation is taking longer this could affect the changeover process.
Production Manager	Has a great interest with a reduction of the changeover time.
Team Leader of Setter	Knows the problems that come from the setters. And has knowledge about the changeover process.
Technical Manager	Has an interest in a reduction as well. Is also the person that knows what kind of improvements are performed in the past. Possible improvements are discussed with this person to see if it is possible and to see if the solution really solves the problem

3.2 Observations

The original SMED method is analysing the whole changeover process. This research will only focus on the mechanical changeover instead of the whole changeover process. Step 1 explains why there is only focussed on the mechanical changeover process. Based on this analysis there is determined which activities can be moved from the internal process to the external process. The observations are used to write down the activities and the duration of the activities during the mechanical changeover. It is expected that from this list of activities it is easy to identify the bottlenecks in the changeover process. The steps that are taken for the SMED method are explained below:

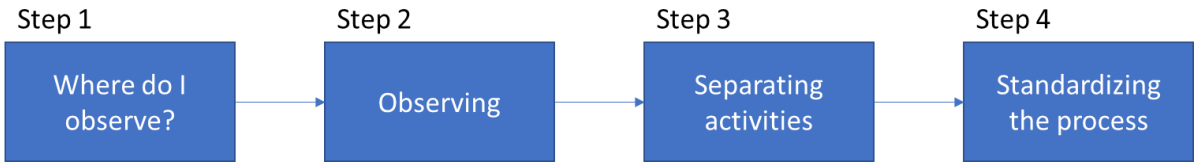


Figure 10: *Overview of the steps taken*

Step 1

The first step in this process was to identify where to start the observations. As described in section 1.3 the production floor consists of 17 mills that are divided into five areas. From these areas P2 and P3 contain the most mills and are responsible for most of the changeover times. The changeover process in both areas is a bit different because the stands that are used in P3 are heavier than the stands used in P2. Because of this, the way of changing over the machine is different as well. Data from the company showed that the duration of the changeover is the longest in P3. Therefore there is chosen to focus on the mills in P3.

After deciding where to conduct the research one must decide at what part of the process is going to be observed. The whole changeover process could take up to a week. The observations can become cluttered when all the activities that happen during a week are written down. So therefore, the focus

lies on a smaller scope of the process. There is chosen to observe the mechanical changeover process. Since the mechanical changeover process is a process that happens in the internal phase of the changeover. The fine-tuning process (which is also part of the internal phase) is not included because this process could take up to a day. It would be unclear to write down all the activities that happen during that time period.

Step 2

In the second step, the observations are performed at the mills. There are some steps that each operator needs to do in order to perform the changeover. It is important to know what these steps are to identify the areas for improvement. Currently there is no specific way how the setter should perform the changeover. The activities that are observed during a changeover are written down in a list with the duration of the activity. Appendix G contains an example of a list that was used during the observation. From the list of activities there can be determined which steps could be moved to the external phase of the changeover process. The list will also help to identify activities that are superfluous.

Step 3

The third step is focussing on moving the internal activities to the external phase of the changeover process. The activities are categorized in order to create a clearer overview of what happened during the changeover. A distinction is made between the effective and ineffective changeover time. The ineffective changeover time consists of activities that do not add value for the company or customer to the product (also referred to as Muda, see section 2.1.1).

- ***Effective changeover time:*** During the changeover there are activities when a setter is actually focussing on changing over the stands or cassettes. The following two categories are part of the time spent on changeover.
    - *Putting stands on the mill:* Time spent on placing the stands on the mill and attaching them with bolts to the mill. Aim is to measure the time that is needed to put the stands on the mill and to attach them to it.
    - *Getting the old stands from the mill:* Time spent on unscrewing the bolts of the stands and lifting them from the mill. Aim is to measure the time needed to detach the stands from the mill and to lift them on a pallet or kart

- ***Ineffective changeover time:*** During the changeover there are also moments when the setter is not directly working on the changeover. These activities are seen as waste since they are not contributing to the changeover. The following six categories are part of the non-changeover time
    - *Getting the new stands:* Time spent on getting the new stands from the repository. Aim is to measure the transportation time from the repository to the mill.
    - *Putting the old stands away:* Time spent on putting the stands back in the repository cassette and lifting them of the mill. Aim is to measure the transportation time from the mill to the repository
    - *Planned losses:* Time lost due to bad planning. A meeting during an on-line changeover is an example of bad planning or if the setter cannot use the crane because someone else is using it. Aim is to measure the time that is lost due to bad planning
    - *Cleaning losses:* Time lost cleaning and tidying up the mill and tools.

- *Time away from the machine:* Time spent away from the mill. This category excludes getting the new stands and putting the old stands away since these are measuring the transportation time.
- *Personal time:* Time spent on personal activities like a bathroom break or drinking coffee.
- *Preparation:* Is the time spent looking at drawings and talking with colleagues about what needs to happen for the changeover. Aim is to measure the time that is needed to prepare for the changeover.

The activities that are written down in the activity list are given a colour to the corresponding category. This is done to make it clear to which category each activity belongs to. A column chart is made for all the observations to visualize where the bottlenecks are in the changeover process. The colours that are used in the column chart will be the same as the colours used in the activity list.

Step 4

The final step is to standardize the process. The new process needs to be standardized and documented to make sure that everyone can work according to the new way. According to Slack et al. (2016) standardization of the processes means activities are performed in a more common way. Letting the setter do the process in their own way can give some form of autonomy. The problem is that there will be confusion, misunderstanding and inefficiency when everyone is doing the process their own way. In order to change the way of working it is important that the setters are involved in creating the new documented process. It is also important that the setters receive instruction about how and why they are changing their way of working. Once the setters understand why they are changing it can become easier to implement solutions.

4 Results

This section gives an overview of the findings from the interviews and the observations that are performed before the implementation of the improvements. The first section gives the key findings from the interviews that are conducted with different stakeholders in the changeover process. See Appendix F for the detailed explanation of the interviews. In the second section the results of the observation are presented. The final section of this chapter combines the findings of the interviews and the observation to conclude on what the bottlenecks are in the current changeover process. The aim of this chapter is to get an answer to the sub-question: ***What are the bottlenecks in the changeover process?***

4.1 Interviews

Table 4: ***Overview of problems mentioned by the stakeholders***

Setter	• Ergonomic problems • Tools are not at the designated place during the changeover • Poor communication • There are to many mistakes in the preparation of the changeover process
Company mechanic	• No preventive maintenance • Bad planning, there are too many moments when a setter of company mechanic need to wait for someone else to finish their job.
Team leader	• To many minor problems that needs to be solved by the team leader • The changeover process needs standardization • Lack of teamwork
Production manager	• Poor communication • The organisation of the process needs improvement, Team lead has not enough time to do their job.
Technical support manager	• Bad organisation of the changeover process (tools are not prepared at the mill, malfunctions cause setters to move to another mill and setters do not start when they have to) • Measuring with the feeler gauge is not a good way of measuring

Table 2 shows the problems that are mentioned by the stakeholders in the changeover process. It can be seen from this table that there are some problems mentioned by multiple stakeholders. These problems are, bad preparation of the changeover process, missing tools during the changeover, poor communication and the team lead is not having enough time to do their job correctly.

The first problem that is mentioned by multiple stakeholders is the bad preparation of the changeover. There are certain tools that need to be prepared before a changeover. These are for example side supports which are prepared by a person in the repository or tools that a setter might need during a changeover. It appears that sometimes side supports are missing or that tools are not at the right place. This causes that the setter has to search for these tools during the changeover.

Tools have a designated place where they are placed after usage. It occurs often that tools are not placed back at the right place. This causes that setters, company mechanics and operators are searching for their tools which is a waste of time.

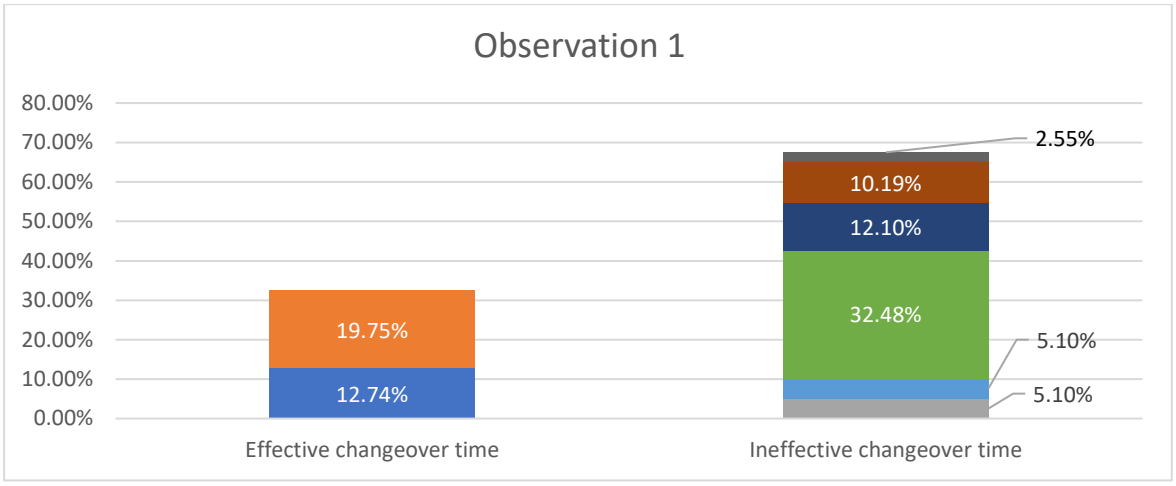
Another problem is the communication. In the past setters were giving ideas and tips on how to improve the changeover process. But nothing is done with these ideas and the setters did not receive any feedback why this was the case. This caused that setters stopped giving ideas for improvement because they feel like they are not taken seriously. The managers and team leaders are saying that this was not the case and that they are in fact giving feedback when they receive ideas for improvement. One of the problems that is mentioned by the technical support manager is the problem with the feeler gauge. He thinks that there are other, more precise ways of measuring the height of the stands. In the past there is tried to implement these new methods, but the setters ignored the new method and kept on using the feeler gauge. This was because the setters think that using the feeler gauge is accurate enough to set the stands at the right height.

The team leader of the setters and the production manager told during the interviews that team leaders are not having enough time to do their job correctly. One of the reasons mentioned by the team leader was that he receives constantly phone calls from setters, operators or company mechanics during minor problems. According to the team lead there is not enough time to monitor and solve all the minor problems.

4.2 Observations

The changeovers that are observed during observation 1 and observation 2 were changeovers with cassettes (see section 1.3.2). Observation 3 and Observation 4 were observations at a mill that made use of single stands. The duration of the changeovers are shown in table 2. In this table are the activities which are part of the ineffective changeover time red. These activities are not adding value to the company or to the customer and are therefore seen as waste. The amount of stands that went on and from the mill during the changeover are approximately the same for all observations (between 20 and 24 stands). The filled in activity lists is found in Appendix G . There is decided not to look at the fine-tuning process. This process is a concerning bottleneck within the changeover process but there was not enough time to get enough data on the fine tuning process. The fine tuning process could take several hours or days which makes it complicated to apply the SMED method. The importance of reducing the duration of the fine tuning process can be seen just from the duration. Therefore it is discussed in section 6.3 that discusses the recommendations for the company.

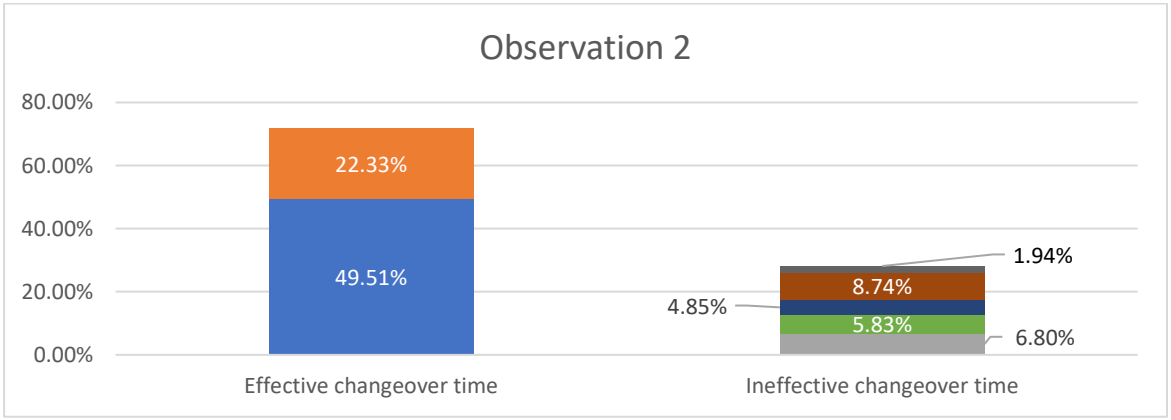
Observation 1



Personal time		2,55%
Away from Mill		10,19%
Cleaning		12,10%
Planning		32,48%
Putting old stands away		5,10%
Getting new stands		0,00%
Preparation		5,10%
Lifting stands from the mill	19,75%	
Putting stands on the mill	12,74%	

Figure 11: ***Overview of activities during observation 1***

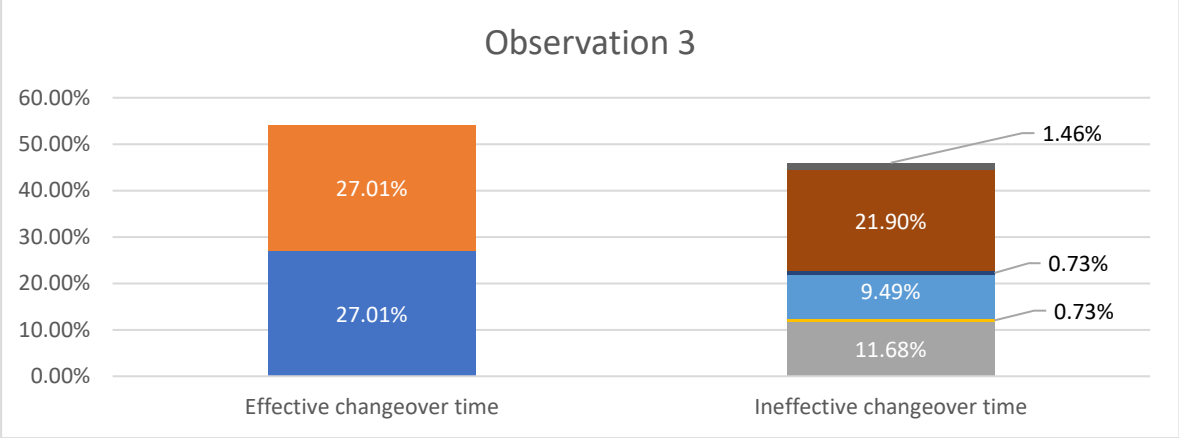
Observation 2



Personal time		1,94%
Away from Mill		8,74%
Cleaning		4,85%
Planning		5,83%
Putting old stands away		0,00%
Getting new stands		0,00%
Preparation		6,80%
Lifting stands from the mill	22,33%	
Putting stands on the mill	49,51%	

Figure 12: ***Overview of activities during observation 2***

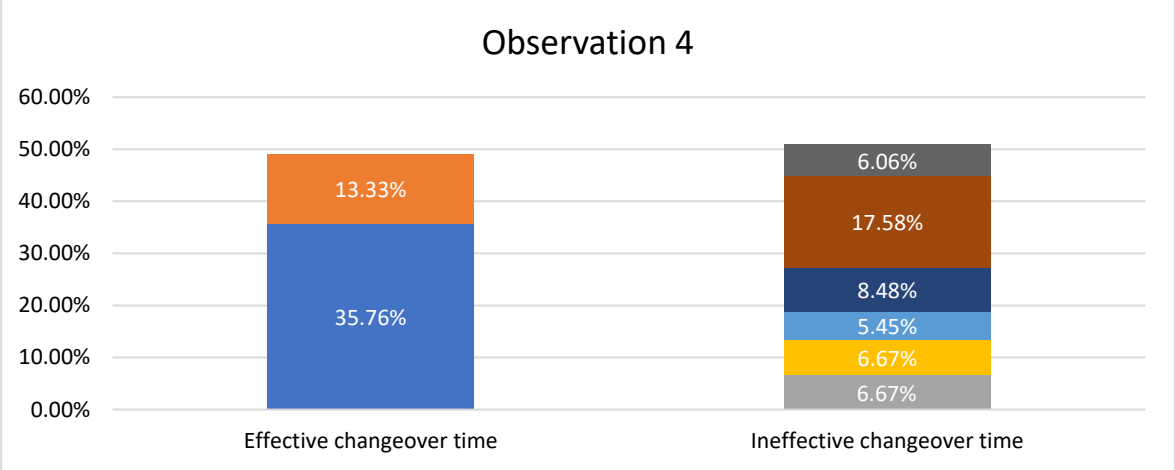
Observation 3



Personal time		1,46%
Away from Mill		21,90%
Cleaning		0,73%
Planning		0,00%
Putting old stands away		9,49%
Getting new stands		0,73%
Preparation		11,68%
Lifting stands from the mill	27,01%	
Putting stands on the mill	27,01%	

Figure 13: ***Overview of activities during observation 3***

Observation 4



Personal time		6,06%
Away from Mill		17,58%
Cleaning		8,48%
Planning		0,00%
Putting old stands away		5,45%
Getting new stands		6,67%
Preparation		6,67%
Lifting stands from the mill	13,33%	
Putting stands on the mill	35,76%	

Figure 14: ***Overview of activities during observation 4***

Table 5: *Overview of the time spent on the activities during the changeovers.*

	Observation 1	Observation 2	Observation 3	Observation 4	Average
Putting stands on the mill	00:20:00	00:51:00	00:37:00	00:59:00	00:41:45
Lifting the stands from the mill	00:31:00	00:23:00	00:37:00	00:22:00	00:28:15
Preparation	00:08:00	00:07:00	00:16:00	00:11:00	00:10:30
Getting the new stands	00:00:00	00:00:00	00:01:00	00:11:00	00:03:00
Putting the old stands away	00:08:00	00:00:00	00:13:00	00:09:00	00:07:30
Planned losses	00:51:00	00:06:00	00:00:00	00:00:00	00:14:15
Cleaning losses	00:19:00	00:05:00	00:01:00	00:14:00	00:09:45
Time away form mill	00:16:00	00:09:00	00:30:00	00:29:00	00:21:00
Personal time	00:04:00	00:02:00	00:02:00	00:10:00	00:04:30
Total	**02:37:00**	**01:43:00**	**02:17:00**	**02:45:00**	
Total waste	01:46:00	00:29:00	01:03:00	01:24:00	

There are four things that can be concluded from the figures and the table that are shown above. The first thing is that the activity “time spent away from the mill” is on average demanding the most from the ineffective changeover time (See table 2). Reasons for the setter to leave the mill are that the tools were not ready at the mill at the start of the changeover, the setter was getting empty pallets for the old stands and talking with colleagues. The second thing that can be concluded is that during the observations with the single stands (observation 3 and 4) time is wasted on the transportation of the stands. Single stands are not prepared at the mill since the setter thinks that the stands will hinder other employees. Therefore the stands are brought from the shelves to the mill once there is space on the mill. During observation 1 there was also time lost on the transporting the cassettes to the repository, but this was the only activity the setter could do at the moment because he had to wait for the company mechanic to continue his work.

From table 2 it can be seen that on average ten minutes and thirty seconds is spent on the preparation of the changeover. This includes activities like looking at the drawings for the changeover, checking the mill and talking with colleagues about if there is something special that needs to be done during the changeover. Especially looking at the drawing took a lot of time since the setter had to move away from where they were working and look at a pc on how to assemble the stands to the mill. The frequency of how much this happened caused the time spent on the preparation

Finally, it can be seen that there is also a significant amount of time spent on cleaning the tools or the mill. Some tools are cleaned if they are not needed anymore for the changeover. Once the tools are clean they are placed back at the designated place. Besides cleaning the tools the mill is cleaned as well. The mill could be dirty depending on the production and therefore it is cleaned when the stands are from the mill. This way the setter can easily clean the mill. Note that there is also time spent on planned losses during observation 1 and 2. This was because of scheduled meetings that were only possible at that specific time.

4.3 Conclusion

The aim of this chapter is to find an answer to the sub question: *What are the bottlenecks in the changeover process?* Based on the result of the interviews and observations there can be concluded that there are three core problems.

Preparation

There are too many mistakes happening in the preparation of the changeover process. It can be seen from the observations that there is too much time spent on the activity “away from the mill”. One of the main reasons is that the setters were searching for tools during the changeover. When searching

for his tools there is a chance that the setter gets distracted by other colleagues which increases the downtime as well. The stakeholders know that this is a problem since it was mentioned during the interviews Therefore the preparation of the changeover process is seen as one of the bottlenecks.

Transportation

The transportation of the stands is a bottleneck as well. When comparing observations 1 and 2 with observations 3 and 4, it can be seen that 3 and 4 are spending more time on the transportation of the stands. The reason for this is that the setters think that it is not possible to prepare the single stands at the mill before the changeover starts. Stakeholders are not directly mentioning problems with the transportation of the stands, but they are mentioning that there are problems with the organisation of the process.

Communication

The final bottleneck in the process is the communication. Multiple stakeholders are mentioning that there is a poor communication in the company. This poor communication causes that setters are not willing to give their ideas on how to improve the changeover process, mistakes that occurred in the past are constantly reoccurring and problems with for example ergonomics are not solved. The poor communication cannot directly be linked to the observations. But it could be that the poor communication causes that there are still tools missing during the changeovers.

5 Suggested solutions.

This chapter introduces the solutions that are based on the results from the interviews and the observations. It gives the suggested solutions with the reason why this solution is expected to have an impact on the changeover time.

5.1 Solutions

From the results in chapter it can be seen that the key problems are the preparation, transportation and communication. This chapter suggests solutions for the three core problems. The final solution could also contribute to improvements in the organisation of the process. There is brainstormed with the technical support manager, setter and the team lead of the setters about possible solutions that focus on reducing or removing these problems from the changeover process the brainstorm session gave the following solutions:

Solutions for the preparation

- *Print the drawing that mentions where to put the joints of the machine:* At the moment the setters are looking for a lot at the computer to see what they need to do for the changeover. This makes the setter turn away from the machine. In order to reduce the motion, the important documents that are needed are printed. The idea is that the setter does not have to turn to the computer to look at the drawing. A downside of this solution is that the company was focussing on digitalising everything and this would be a step back from that.
- *Preparing the tools for the changeover:* There are a lot of tools required for the changeover therefore it is important that everything is ready at the start so that the setter does not have to look at other mills for tools or materials. With this solution there is expected to reduce the motions during the changeover. Since the setter knows where his tools are, and the tools are close to him. Besides that, this solution contributes to 5s since the tools that are needed are prepared closer to the setter. Preparing the tools for the changeover takes some time and therefore it should be communicated on time to the setter.

Solutions for the transportation

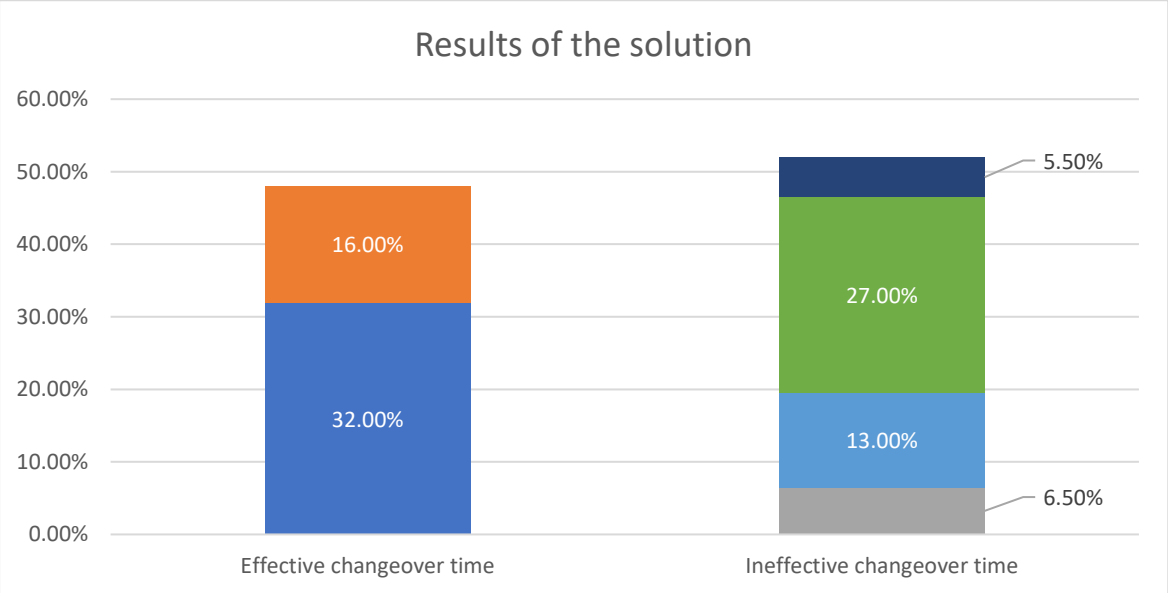
- *Prepare the stands an hour before the expected changeover:* This will be for the mills that require stands and cassettes. Currently the cassettes are placed at the mill way to long before production ends. This causes that the stands are hindering the operator and other people that need to do their tasks. The mills with the single stands are most of the time not ready at the mill when the changeover starts. A reason for that is that there is very little space between the mills. This solution is trying to reduce the transportation time between the repository and the mill during the changeover. At the same time this solution aims to contribute to 5s since the cassettes are only waiting at the mill short before the changeover starts. A trade-off of this solution is that the stands are still one hour taking space at the mill.
- *Use the pallets of the new stands for the old stands as well:* This can only be performed for the mills with the single stands. The main idea is to use the pallet of the new stands for the old stands. Once the new stands are put on the machine an empty pallet remains. This pallet will be used for the old stands that are still on the mill. There is expected that this will reduce the transportation time between the mill and the repository since there. It is important that if this solution is implemented the setters are trained or at least informed about how to perform the new step in the changeover process.

Solutions for the communication and organisation

- *Doing the mechanical changeover with 2 persons instead of 1:* The mechanical changeover can be done with two persons instead of one. The idea is that one person focusses on lifting the stands on the mill while the other one is already cleaning, attaching and detaching the stands from the mill. This solution focusses on reducing the amount of time spent on cleaning and the time spent on attaching and detaching the stands. The second person could be an operator if the operator has enough knowledge on how to perform the mechanical changeover. When implanting this solution there must be thought of the extra costs of the second setter. The second setter must reduce the changeover time in such a way that extra costs of the setter are compensated by the gains from the reduction in the changeover time.

5.2 Results

This section gives an overview of the results that are achieved by implementing the solutions to the current changeover process. The purpose of this section is to show the impact of the improvements on the current changeover process. The suggested solutions are applied once during a changeover with single stands. This changeover took place on



Personal time		0,00%
Away from Mill		0,00%
Cleaning		5,50%
Planning		27,00%
Putting old stands away		13,00%
Getting new stands		0,00%
Preparation		6,50%
Lifting stands from the mill	16,00%	
Putting stands on the mill	32,00%	

Figure 15: Results of the suggested solutions

The observation was during a changeover with single stands. The total duration of the changeover was 1 hours and 40 minutes. There were 21 stand that got off the mill and 20 stands that got onto the mill. This is approximately similar to the amount of stands that are used in the observations from

chapter 4. The time spent on the changeover was 48% of the total changeover time. Most of the time was spent on getting the stands on the mill and attaching them. The non-changeover time was 52% of the total changeover time. From the non-changeover time the time spent on a meeting took the most amount of time. There was no time away from the mill since everything was ready at the mill at the start of the changeover. The start of the changeover happened with one setter and after an hour a second setter joined to help during the changeover. The other setter could not help earlier because there was other work left that first needed to be completed. There were still moments when the setter had to look something up at the computer. It can be seen that there is still time spent on moving the stands to the repository. The reason for that is that the pallets with the stands could not be placed on the floor close to the mill. It would be in the way for the company mechanic that needed to do his work.

Putting the stands on and off the mill is lower after the implementation of the solutions. A reason for this could be that the setter is performing less motions with the forklift. When the new stands are lifted on the mill the old stands are slid back on the empty pallet.

	Avg. Duration Curren process	Duration new method	Difference in minutes
Putting stands on the mill	00:41:45	00:32:00	9,75
Lifting the stands from the mill	00:28:15	00:16:00	12,25
Preparation	00:10:30	00:06:30	4
Getting the new stands	00:03:00	00:00:00	3
Putting the old stands away	00:11:00	00:13:00	-2
Planned losses	-	-	-
Cleaning losses	00:09:45	00:05:30	4,25
Time away form mill	00:21:00	00:00:00	21
Personal time	00:04:30	00:00:00	4,5
Total	**02:24:00**	**01:40:00**	**00:56:45**

Table 6: Duration comparison between the current situation and the new method

Table 4 shows the comparison between the average duration of the activities of the current situation and the duration of the new method. The right columns shows the amount of time that is saved by implementing the new method. It can be seen that the most amount of time is gained on the category “time away from mill”. Planned losses are not used in this tables since planned losses are currently not used for the calculation of the OEE by the company. The planned losses are currently used to show the company that they indeed should be used for the calculation of the company since the planned losses are taking a significant amount of time of the changeover process.

From this table it can be seen that the new method saves almost 57 minutes on a changeover process. In order to say something about the effect of the solutions on the OEE there is assumed that the quality level and the performance level of the OEE are fixed at 100% and 65% respectively. The reason for this is that the current quality level is already fixed at 100%. From figure 17 in appendix B it can be seen that last year 52% was spent on production. The production time is in this case also the availability level. Section 1.2 shows that the availability level is determined by the production time divided by the net. operating time. The average OEE of last year was 33.8%. when all the variables are filled in it can be calculated that the average performance level of last year was 65%, see the calculation below.

$$OEE = AL \times PL \times QL \rightarrow 0.338 = 0.52 \times PL \times 1.0 \rightarrow PL = \frac{0.338}{0.52} \times 1.0 = 0.65 = 65\%$$

Where AL is the availability level, PL is the performance level and QL the quality level.

There is also assumed that the net. operating time remains the same. Therefore the time gained with the suggested solutions is directly added to the production time. To find out the effect of the solutions to the OEE one must know what the net. operating time and production time is. These number are derived from figure 17 in Appendix B. From this figure it can be seen that 111 hours per week represents 15% of the net. operating time. This holds that the net operating time is equal to 742 hours per week and the production time is 385 hours per week. The time gained per week is on average 10 hours, which indicates that the production time is now 395 hours per week. To calculate the availability level one must divide the production time by the net. operating time, which is 395/742*100= 53.3%. Multiplying the new availability level with the performance and quality level results in a OEE of 53.4%*65%*100% = 34.6%. There are things that may cause that the OEE in reality differs from this calculation. These things are discussed in the next chapter.

	Costs in current situation	Cost with new method	Difference in euros
Putting stands on the mill	€ 55,67	€ 42,67	€ 13,00
Lifting the stands from the mill	€ 37,67	€ 21,33	€ 16,33
Preparation	€ 14,00	€ 8,67	€ 5,33
Getting the new stands	€ 4,00	€ 0,00	€ 4,00
Putting the old stands away	€ 14,67	€ 17,33	-€ 2,67
Planned losses			
Cleaning losses	€ 13,00	€ 7,33	€ 5,67
Time away form mill	€ 28,00	€ 0,00	€ 28,00
Personal time	€ 6,00	€ 0,00	€ 6,00
Total	**€ 173,00**	**€ 97,33**	**€ 75,67**
Yearly base	**€ 77.850,00**	**€ 43.800,00**	**€ 34.050,00**

Table 7: Cost comparison between the current situation and the new method

Table 5 shows the comparison between the costs that are made in the current situation and the costs that could be made based on the new method. The right column shows the difference in cost for each activity. The total costs shows the average of the total costs that are made when a changeover happens in the current situation, the total costs if the changeover would happen with the new method and the difference in costs between the methods.

The costs are based on a cost price of 80 euros per hour that is used by the company. On a weekly basis there are eight to ten changeovers happening. Therefore to calculate the total amount of changeovers in a year there is decided to go with nine changeovers on average per week. Since the company is closed for 2 weeks each year the total amount of changeovers is estimated to be 50*9 = 450 changeovers a year. In order to calculate the costs that are made on a yearly base on the changeovers the estimated number of changeovers is multiplied by the total amount of costs for the mechanical changeover.

5.3 Implementation plan

There are several steps that are needed to implement the solutions that are suggested in the current changeover process. Some of these improvements require extra preparation time and it cannot be expected from the setters to understand the new way of working immediately.

A first step in this process is to determine what tools and drawings are needed for a changeover. The company already have documents that contain information about what tools are needed for the changeover. Besides that it is also important to remove the tools that are not needed during the

changeover. This makes it easier for a setter to see if all the right tools are ready before the start of the changeover. After determining which are needed for a changeover it is important that this is documented in a checklist which a setter must use before the start of a changeover.

The next step is to inform the setters with the new method and explaining to them how the new method is performed and the reason for adjusting the current method. From the interviews it became clear that the setters were missing feedback from the management on why certain adjustments were made. So therefore it is important that when changes are made this is communicated to the setters.

Now that the setters know how to perform the new method it can be applied to one or two mills for a few weeks to find the flaws of the method and to improve certain steps. Once the method is optimised it can be applied to more mills, for example all P3 mills. If this goes good as well one could extend the method to another production area to see if the method works there as well. This goes on until all the production areas are changed over according to the new method.

It is important that during this process there is constantly asked for feedback from the setters. They know if something does not work. In that case there must be thought of something else. Figure 16 visualises the steps that are taken to implement this plan to the current changeover process.

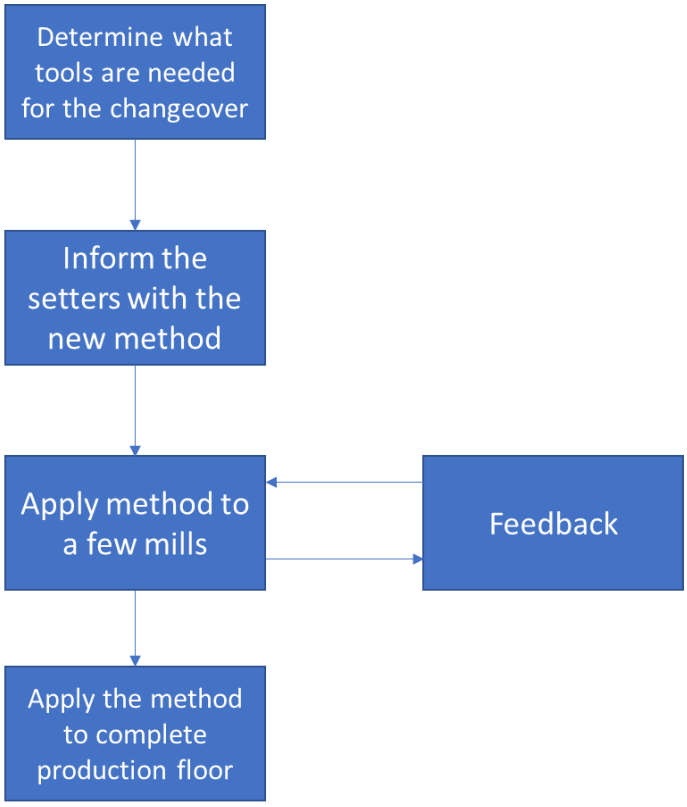


Figure 16: ***Steps for the implementation plan***

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6 Conclusion and Discussion

6.1 Conclusion

This chapter discusses the conclusions and the most important findings from the results of this research. The focus of this research is to improve the OEE at Hadley. In order to do so there is tried to reduce the changeover time. The data from the company showed that the changeovers take the most amount of time from the total downtimes. To reduce the changeover time the following question is asked:

How can the changeover time be reduced to improve the overall equipment effectiveness at Hadley?

For solving this question there are two sub questions formulated. The first sub question is: ***What are the bottlenecks in the changeover process?***. In section 4.3 there is explained that the preparation, the transportation of the stands and the communication in the company are seen as the bottlenecks in the changeover process. Since there are multiple things going wrong in these areas.

The second sub question was: ***Which solution(s) will improve the changeover process?*** For each improvement there is thought of how it will affect the changeover process.

- ***Preparing the stands at the mill***
  This caused that the setter did not have to get the stands from the repository. Therefore there was no time spent on transport for getting the stands to the mill. Since the stands were prepared shortly before the changeover the stands were not in the way for other employees. The old stands were in the way of other employees so therefore there was still time spent on transportation.
- ***Preparing the tools before the changeover.***
  Now that the tools were already at the start of the changeover, the setter did not spent time on searching tools. This also caused that the setter was constantly working at the mill which reduces the chance of being distracted by other employees.
- ***Using the pallets of the new stands for the old stands***
  This solution caused that there was no time spent on getting empty pallets and placing them back in the repository. From the results it can be seen that there was no time spent away from the mill. This is also caused by preparing all the tools at the start of the changeover. It can be concluded that using the pallets of the new stands for the old stands and preparing the tools are solutions that are decreasing the changeover time.
- ***Working with two setters instead of one***
  This only happened partially during the changeover. Due to a low capacity of setters the second setter was only available during the second half of the changeover. This was during the period when the new stands were put on the machine. From the data it can be seen that the amount of time spent on getting the stands on the machine was lower than the first observations with single stands. But from the results there cannot be concluded that the second setter made a difference in the changeover time. Therefore it cannot be concluded that using a second setter is a good solution.
- ***Printing the drawings for the changeover***
  The setter was looking less on the computer now that he had the drawing in front of him. The preparation time was also lower than the preparation time of all the other observations before implementing the solutions. There was still one moment when the setter had to look on the computer to check something. Since the company wants to become more digital this could be a solution for the short term.

The sub-questions helped to answer the research question: *How can the changeover time be reduced to improve the overall equipment effectiveness at Hadley?*

Based on the sub-questions it can be concluded that preparing the stands at the mill, using the pallets of the new stands for the old stands and preparing the tools are improvements that reduce the changeover time in the long run. Printing the drawings could be a short term solution since the company wants to have all the documents online. There cannot be concluded that the costs of the extra setter outweighed the time that is gained. Further research is needed to conclude that it is worth to use a second setter during the changeover. When these solutions are implemented there is estimated that the OEE will improve from 33.8% to 34.6%.

6.2 Discussion

This chapter gives a description about the research that is conducted. There is critically looked at the validity of the research, the results that are obtained, the limitations of the research, implications and the future work.

Methodology

In order to guarantee that the information from the interviews is correctly interpreted, the participants received the piece of information that is related to their interview. The participant would highlight the text that was not written down correctly. Once the participant was happy with what was written down the information was used for the report. The problem with this approach could be that the information is adjusted in the favour of the participant which could affect the

Additionally, the observations are only performed in the P3 area. In order to be sure that the results apply to all the mills the research should be expanded to all the areas of the production floor. In section 1.3.2 it is explained that there are differences in the stands that are used in P3 and P2. This could mean that P2 is dealing with other problems than in P3. This should be considered when future research is conducted.

The implementation of the second setter was not executed as it should be. It is already explained that the second setter could partially help during the changeover because of a meeting. It could be interesting for future research to show the effects of a second setter and what it could bring the company in terms of the OEE.

Limitations of the Research.

The number of observations that are performed is lower than preferred. Reason for this is that planning an observation was more complicated than expected. Due to a low capacity of the setters, not knowing when the production process finishes and malfunctions it was hard to perform an observation under the right circumstances. The results are less reliable, due to the low number of observations. Besides that, the observations are only performed during daytime while there are also changeovers happening during the evening. Therefore, in reality the results can differ from the durations that are observed. The low amount of observations are also caused due to the low capacity of employees. Scheduled changeover were postponed because there was no-one to perform the changeover. For future research it is important to make agreements on when to conduct the observations with the team leaders since they are the ones that are monitoring the changeovers. There were some agreements but the team leaders sometimes forgot to communicate when a changeover started.

This study does only focus on the mechanical changeover instead of the whole changeover. In order to perform the SMED method perfectly one has to include the whole changeover process. Since the whole changeover process could take up to a week there has been decided to only focus on the mechanical changeovers. It could be that preparing the stands at the mill or preparing the tools at the machine could cause problems in the preparation of the changeover.

Another thing that should be considered is that the observations are only performed in the P3 area. Therefore it could be interesting to start doing research for the mills in P2. It is also interesting to see if the improvements that are applied in P3 will deliver the same result in P2. Besides that there could be other problems related to the changeover process that happen in P2 but not in P3.

This research is focused on reducing the changeover time by finding the bottlenecks in the mechanical changeover process. Besides the mechanical changeover process it is interesting to do research into how the fine tuning process could be changed to reduce the changeover time. In this research there is not focussed on the fine tuning process since it would take too much time. During the fine tuning process are the stands adjusted based on the feeling of the setter. This activity makes it very likely that mistakes will happen later on in the process since the feeling of a setter is not a very precise measurement. Once the fine tuning process is more based on precise measuring rather than feeling, the process can become more stable and predictable. The technical support manager mentioned that projects were started in the past to make the process less based on the feeling of a setter. The only problem that happened at that moment was that the setters were against the idea since adjusting the stands was something that made the job fun. So if there will be changes within the fine tuning process there should be thought of the setters that can cause resistance for new changes. A first step in making the fine tuning process more stable is to show how accurate the feeler gauge is that the current setters are using.

In the problem cluster in appendix A it can be seen that under the performance level there is a problem that is described as “uncertainty of properties of raw material”. This uncertainty causes that sometimes the changeovers take longer than expected. This is not calculated or used in the observations. It could be interesting for the future how this uncertainty could be removed from the process. The company could sort the raw-material based on the specifications of the material. In this way the company could maybe predict the behaviour of the material and change the production process on it.

Implications

This research shows that with the SMED method the changeover time can be reduced. The changeover with the single stand showed that the changeover could be completed an hour quicker than the changeover before the improvements. Therefore, this research could be the start of a project for the company to actually start implementing changes to the changeover process. When reducing the changeover time does not become a priority in the near future the company will make unnecessary costs. The results showed that working according to the new method could save approximately 30.000 euro each year. These are only the costs that can directly be linked to the mechanical changeover time.

Another reason why the company should improve on the changeover time is that there are a lot of benefits besides a reduction in downtime. Section 2.2 tells that besides a reduction in the changeover time the company could also experience a decrease in inventory, improvement of the productivity and an improvement in flexibility.

6.3 Recommendations

There are some recommendations that are based on the organizational level and some that are focused on the technical level.

Recommendations based on results from suggested solutions.

Results from suggested solutions

From the result there are three things that I recommend the company should start using or focussing on. The recommendations are as follows:

- Start using the pallets that are used for the new stands to put the old stands on. From the results it can be seen that the amount of time spent away from the mill is reduced to zero. This is not completely due to this solution but it does play an important role in the reduction of the time. Another possible benefit might be that the time spent on the actual changeover is reduced as well. But this cannot be said with certainty.
- The following thing that the company needs to do is to find a way to make it easier for the person that performs the changeover to find the important drawings. The preparation time is shorter compared to the preparation time in the current situation.
- The final thing that the company needs to do based on the results is to start focussing on the preparation of the changeover process. From the observations it can be seen that there was no time spent away from the mill searching for tools, getting empty pallets or talking with colleagues. This was because the setter had every tool, he needed to complete the changeover. To improve the preparation of the changeover a checklist should be used. This list will prevent that certain tools are forgotten or missing for the changeover.

Further recommendations

Other than the recommendations based on the results there are also recommendations based on the interviews and the literature. These recommendations are divided into multiple sections to show where the recommendation contributes to.

Standardization

- It is important that the start and the end of the changeover is defined and explained to the employees that are performing the changeover. Currently the setter starts measuring the changeover time when he arrives at the mill. But it could be that the production already stopped for several minutes which are not measured. So, to get a better understanding of how much time is lost during the changeovers this should be defined more clearly.
- Another thing that needs to happen is that the changeovers are performed in the same way by each setter. Section 2.1.1 explains that when the changeover process is performed in the same way that the output of the process becomes more stable and shows less variation. This means that the changeover process becomes more predictable which is good if you want to predict when the process starts or finishes. In order to make everyone perform the changeover in the same way there needs to come an execution sequence about how the changeover should be performed.
- In order to deal with the low capacity, the company should focus to give training to the employees so that they are not only specialized to do one task. Currently there are a few operators that are able to perform some tasks of the changeover process which already gives the company more flexibility. Section 2.3 of the literature also mentions that with more flexibility that the company is able to focus the capacity of the company to the process that needs it most at that specific moment.

Communication

- From the interviews and the observations, it became clear that there is currently no urge to perform for the setters. The setters do not realise that during the changeover the company is losing money. In the current situation setters are not feeling some kind of pressure to perform a changeover. Therefore the company should start using a performance indicator to show the setter how they performed during a changeover. The time spent on a changeover or the amount of waste created during a changeover are examples of indicators that the company could use. Using these indicators will make the setter realise that they cannot just use hours to do a changeover.
- The company should start listening to the ideas of the setters or create a moment each month where ideas about improving the changeover process are shared with managers or team leaders. It can be seen from the interviews that the setters feel like they are not heard by the team leaders and managers. The team leader mentioned that there is the possibility to give ideas during meetings but this is apparently not clear to the setters. The company should communicate and stimulate the setters to come up with ideas to improve the changeover process.

Registration

- Start registering the quality level of the OEE. The quality level is one of the three factors that is needed to calculate the OEE. Since the OEE is the most important KPI of the company it must be included in the calculation. The quality level represents the amount of products that are produced correctly. So in order to calculate the quality level the operators should start writing down the amount of products that are produced wrong. When the quality level gets included in the calculation of the OEE it becomes easier to identify where the waste is in the process.
- Besides including the quality level, I also recommend the company to apply 5s to the registration of the variables. At the moment there are a lot of variables that are not used or should not be used anymore. There are also variables that are not used for the calculations of the changeover time that probably should be used. Currently the company is not seeing the time spent on a meeting during a changeover as time spent on a changeover. During the meeting the mill is standing still as well and therefore the time during a meeting should also be included for calculating the changeover time.

Fine tuning process

- The final thing I would recommend is to start measuring the accuracy of the feeler gauge. During the interviews the technical support manager mentioned that measuring with the feeler gauge is not very precise. This causes that in the current changeover process to much time is spent on getting the gaps of the stands at right width. In the past there is tried to implement new ways of measuring the gap, but this halted because this would remove the fun from the job. Measuring the accuracy of the feeler gauge could make the setters realise that a different way of measuring is needed.

Practical contribution

The practical contribution of this study is to provide the company with solutions that are focused on increasing the OEE, with as main focus solutions for the reduction of the changeover time. It provides recommendations that could help the managers make a step in the improvement of the changeover process. The results show the problems in the current changeover process and the problems that are experienced by the employees.

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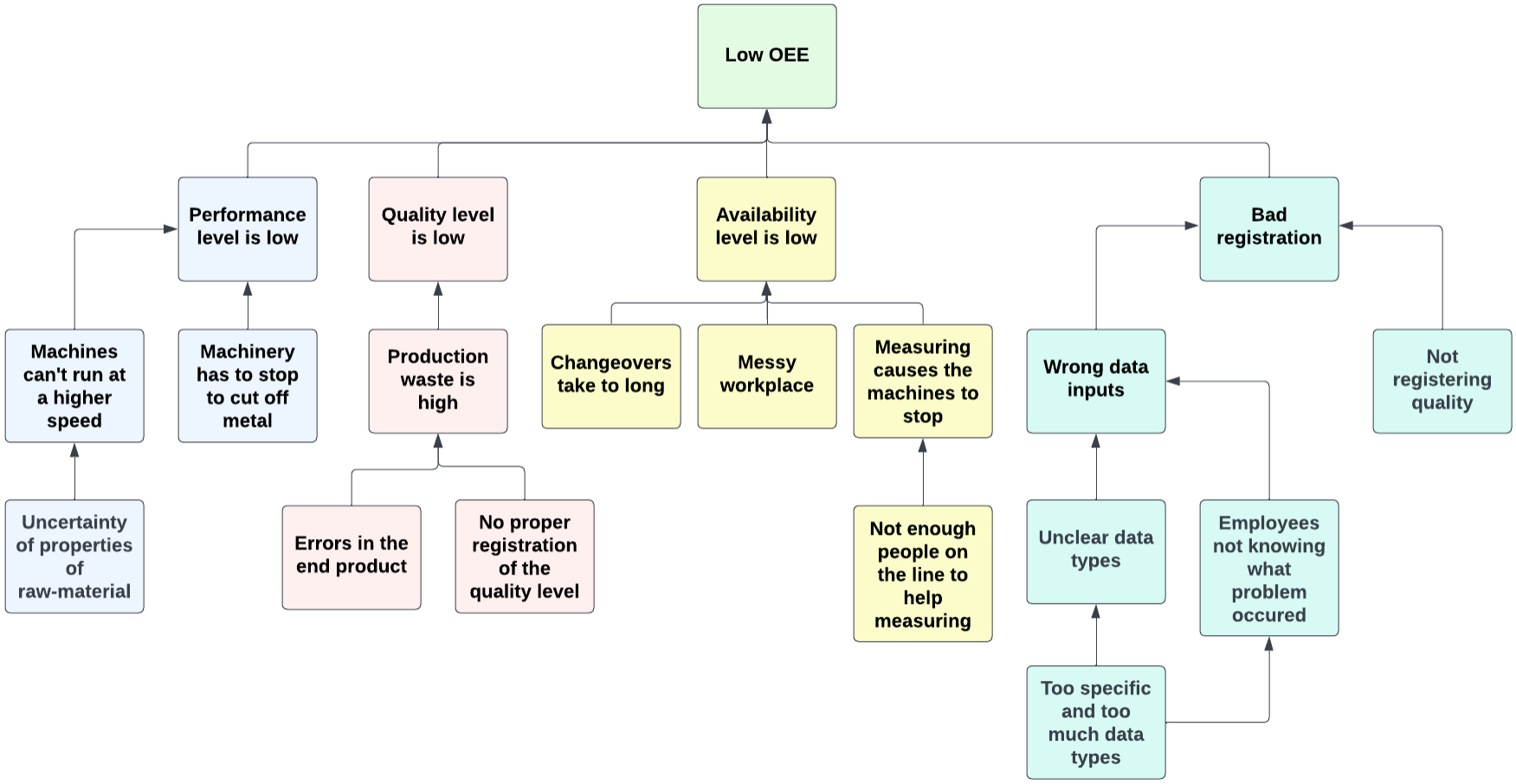
Appendix A Problem cluster



Appendix B Time spent on activities

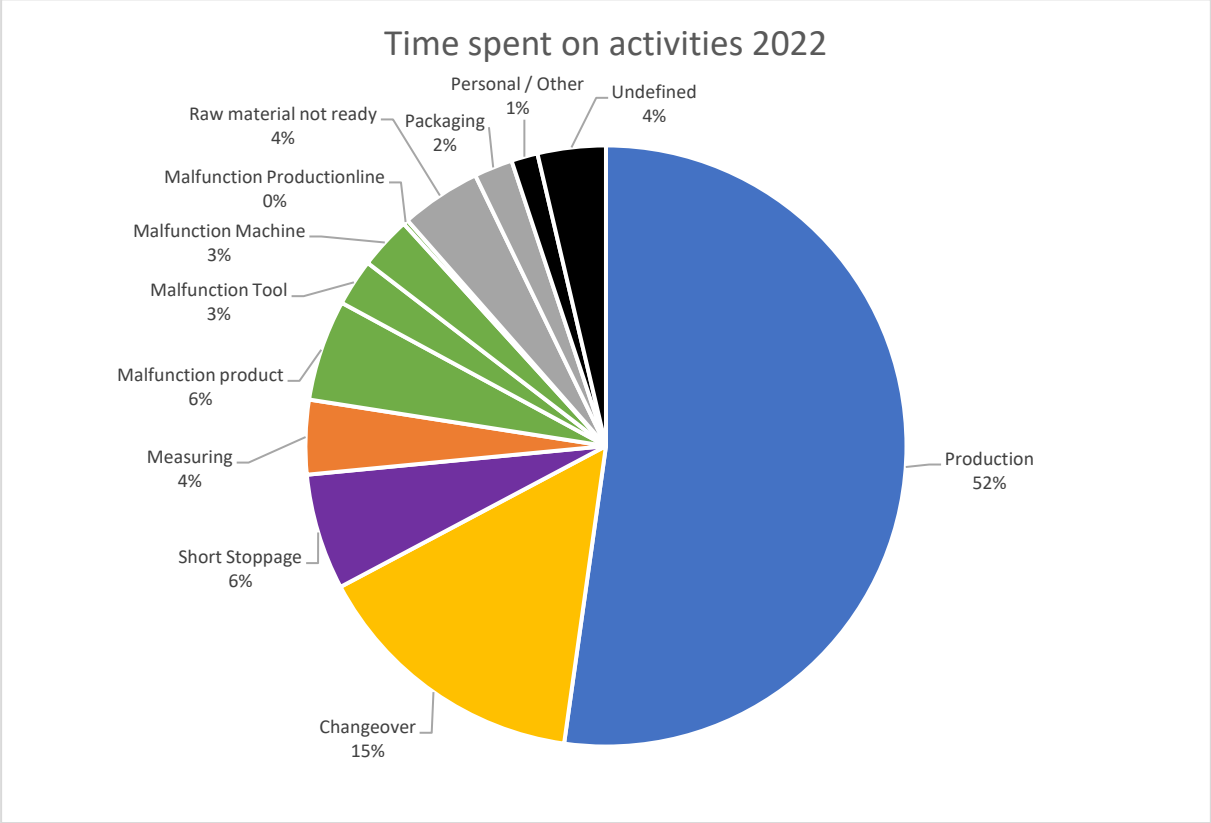


Figure 17: ***time spent on activities in percentages.***

This pie chart represents all the activities that happen during the net operating time. From this pie chart it can be seen that the production time is 52% of the net operating time. The other 48% is spent on activities when there is no production. From all the downtimes that are measured the changeover time is the most demanding with 15%. Since the changeover time is the most demanding from all the other downtimes, there is decided to focus on reducing the changeover time.

Besides the changeover time there are other activities that are causing a lot of downtime as well. These are briefly discussed below:

- *Malfunctions:* Malfunction product, malfunction tool, malfunction production line and malfunction machine are all falling under the total malfunction time. The total malfunction time is 12% of the total net operating time of 2022.
- *Measuring:* During the production and the changeover process it is important that the profile is measured. This is important because during production the profile changes. Sometimes when the profile is measured the machine is standing still for the operator or setter to perform the measurements. This time is used for the calculation of the OEE.
- *Short stoppage:* Short stoppages are stoppages that occur when the machine is standing still for less than four minutes. After these four minutes the operator needs to fill in why the machine is standing still.
- *Material/packaging not ready:* There can also be seen that production is halted due to a shortage of packaging material or raw-material. It could be that due to a miscalculation the amount of packaging material is too low. When there is no packaging material the

production has to wait until there is packaging material. The same story goes for the raw material. Combined this is 6% of the total net operating time.

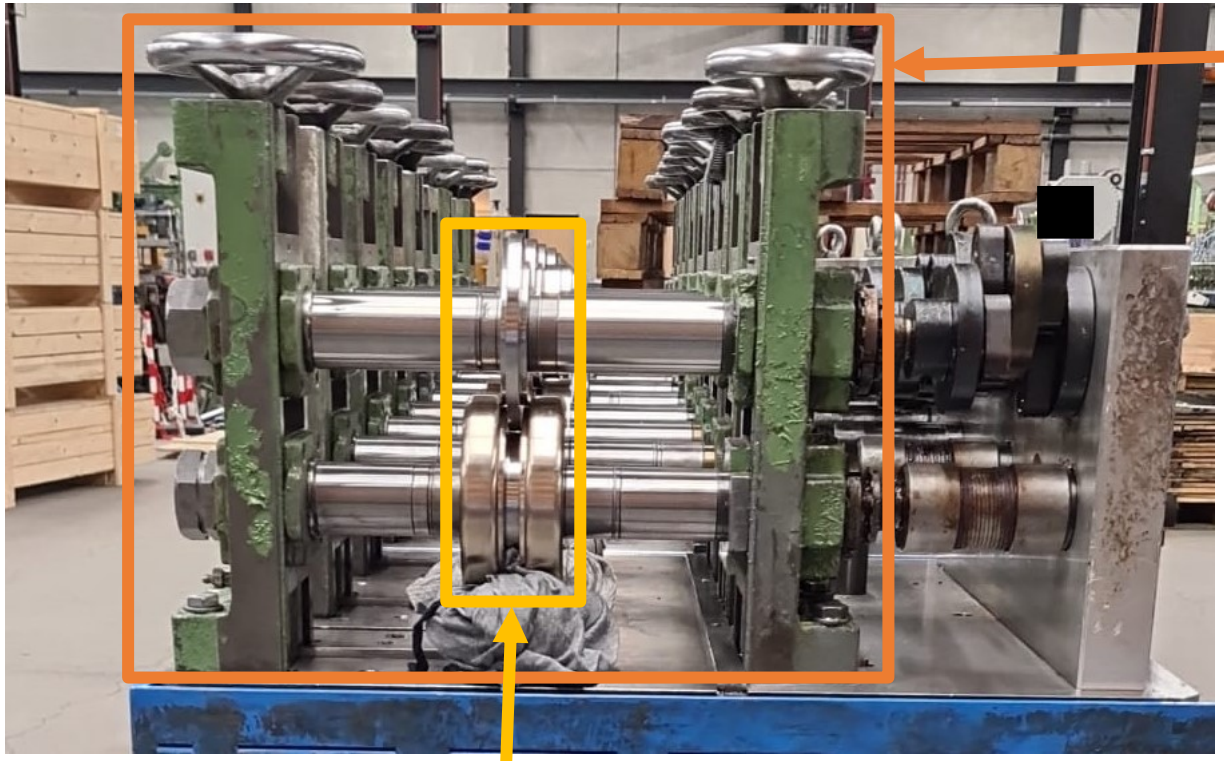
- *Personal/Undefined:* 5% of the time is lost due to personal reasons and by undefined. Undefined appears when the machine is standing still for longer than 4 minutes and the operator or setter did not give an input for the reason why the machine is standing still. Personal time is the time the operator goes to the toilet or when he is going to get some coffee.

Appendix C Problem Solving Approach

Table 8: ***Problem Solving Approach***

Phase 1	**Defining the Problem**
Phase 2	**Formulating the Approach** • Consists of the plan on how the problem is going to be solved.
Phase 3	**Analysing the Problem** • To come up with an improvement there has to be looked at what the biggest problems are at the moment.
Phase 4	**Formulating Solutions** • Solutions are formulated based on the observations and interviews that are conducted
Phase 5	**Choosing a Solution** • From the solutions that are created there will be looked at which are the most suitable
Phase 6	**Implementing the Solution** • Solutions that are thought of will be implemented
Phase 7	**Evaluating the Solution** • Here will be looked at what the effect of the implemented solution has on the changeover time • This phase consists of the recommendations as well.

Appendix D Image of Stand



The green sides and the rollers in the middle are combined called a stand. There are multiple stands behind each other in order to bend the metal. The machine where the stands are standing on during production is called the mill

Figure 18: *Image of multiple stands*

These two parts are the rollers of the machine. They are attached on an axle which is attached to the green sides.

Appendix E Production Floor

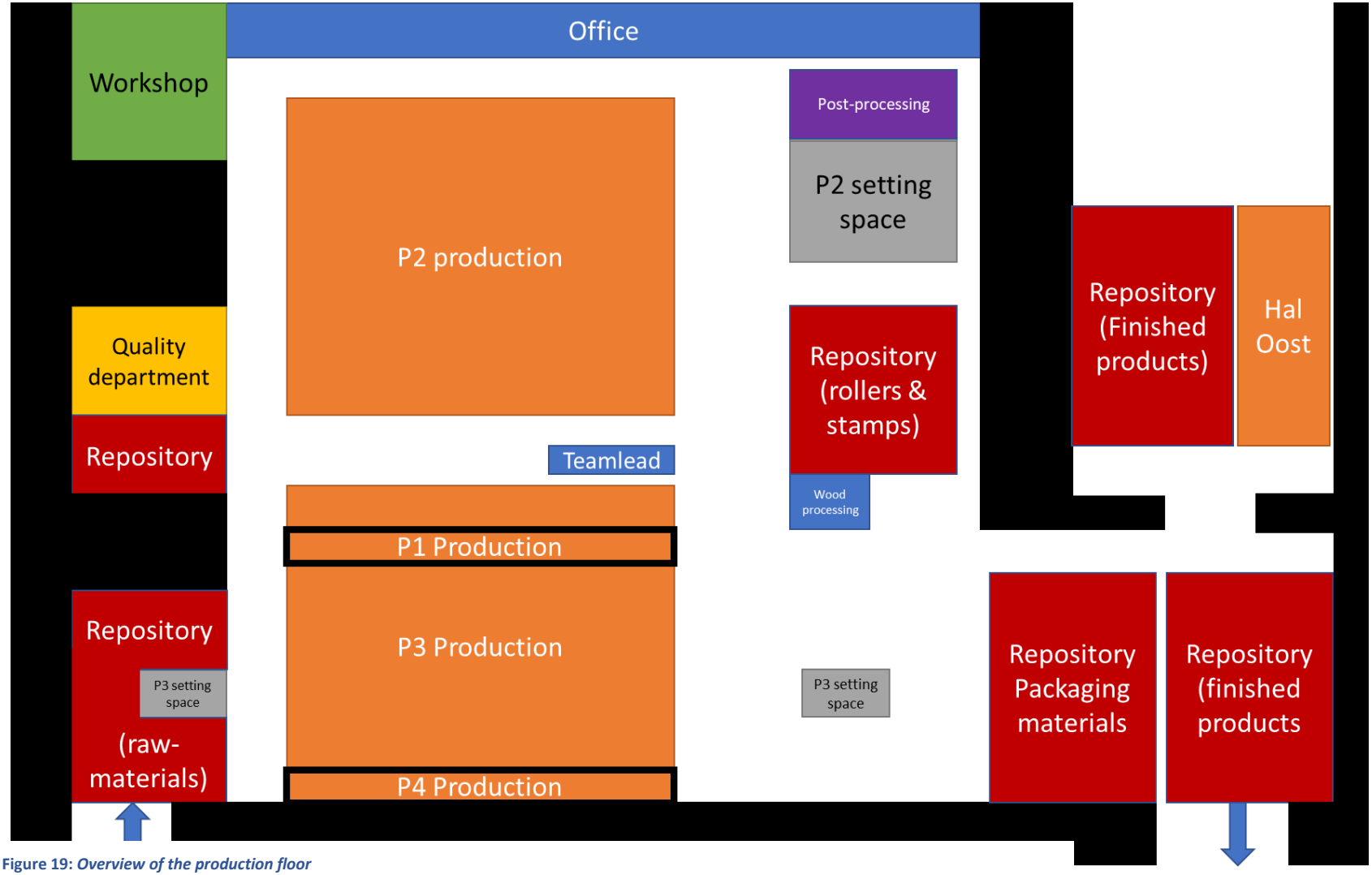


Figure 19: *Overview of the production floor*

Appendix F Interviews

Interview scheme

Name:

Function:

Introduction

Telling who I am and what I am doing. Saying that I am conducting research to the changeover process and that I have some questions about it. Mention that the answers are used in the report and that some people in the company will get to see what is said during the interview. After the interview is conducted the participant will receive the piece of information that is used for the research to validate that what is written down is what is meant.

Questions

- What is your function title?
- What is your role in the company?
- What kind of role does the changeover process has on your daily tasks?
- According to you, what are the biggest problems regarding the changeover process?
- Do you feel like you are able to address problems about the changeover process to your team leader or manager? (Only for setters or company mechanics)
- Do you feel like the setters or company mechanics are telling when there are problems regarding the changeover process? (Only for team leader or managers)

End

Thank the participant for their time and mention again that the information that will be put in the report is first send to them. If there is anything wrong with the information they should highlight the text that is not correct and then I will look with the participant if there is a way to put it in the report. If the participant does not want the piece of information in the report it is removed

Reason for questions

The first two questions are asked to get an impression of what the employee is doing on a day to day basis for the company. Before the interview was conducted, I already had an idea about what the employee was doing. But to confirm these ideas these questions were asked. The third question was asked to see how important the changeover process is for the employee that was interviewed. Question four was asked to find out what the biggest problems are related to the changeover process. It was also used to see if the problems that were mentioned could be seen from the observations. The final two questions were asked to see if the different employees feel the same about reporting problems in the changeover process. Before conducting the interview started there were rumours that the communication between the employees was lacking. So, in order to find out if this was really the case these questions were asked to the different employees.

Worked out Interviews

Setter

There are several ergonomic problems that are mentioned by the setters. The stands that are used in P3 are heavier than the stands in P2 and moving them is quite heavy. In order to move the stands they are either put on a cart that is pushed by one setter or they are moved by a forklift. Moving the stands by cart costs a lot of strength, it is hard to get the cart rolling and to make steer adjustments with the cart. The other thing that is not very ergonomic is that when the stands are moved by a forklift the stands need to be dragged from a pallet onto the machine. This puts the setter in a very awkward position which in the long run can cause back problems. The dragging of the stands happens as well when the stands are assembled or disassembled at the setting area.

The setters also mentioned different problems regarding the tools that are used. First of all, there are a lot of moments when a setter has to search for tools at other mills. Even though tools are having a fixed position. Not only tools are missing but axles and rollers are missing as well. Most of time the tools are found in workplaces from other setters or are hidden in the shelves. A setter will disassemble a stand in the shelve to get the tools he need if he cannot find the right tools.

Some of the setters were also mentioning that the communication between the setters, the team leaders and management should improve as well. Over the years they came up with ideas to improve the changeover process, but they feel like nothing is done with it. They realise that not every idea can be realised but they miss the feedback on why an idea can or cannot be worked out. And when there are changes implemented the setters are not involved in the process. They are the ones doing the changeover and they think that it is important to at least use some setters in the improvement process. Another problem is that the documentation of previous changeovers is not complete or outdated. When the documentation of how to perform the changeover is not updated the setter that is performing the changeover in the future will encounter the same problems and the same time loss.

The last thing that was mentioned by the setters is that there are sometimes support rollers missing when the setter wants to start with the changeover. In the repository the rollers are prepared for the setters according to a checklist. The setters will take the rollers and assemble them into stands or support stands. It sometimes happens that once the changeover starts the setter finds out that there are support stands or rollers missing. When this happens the setter needs to go to the repository and ask the person that is controlling the roller lift to get the rollers needed for the changeover. It could happen that there is no one at the roller lift. Since the persons that are able to use the roller lift are only working during the day, while the setters are also working in the evening. So when the setter finds out the rollers are missing in the evening he will have to wait until the next day before he can get the rollers that are needed.

Company Mechanic

The company mechanic mentioned that the biggest problems regarding the changeovers were caused by malfunctions and bad planning. When a malfunction occurs at a mill while a setter is working on a changeover at another mill, there is a possibility that the setter first has to solve the malfunction at the other mill before he can continue with the changeover. The company mechanic also mentioned that malfunctions can lead to a delay in the changeover time because punching machines or cutting machines are not ready for the changeover. According to the company mechanic there should be more preventive maintenance to prevent the amount of malfunctions

He also mentioned that the changeovers are taking long because of bad planning. Sometimes the company mechanic has to wait for production line to finish in order to move a punching or cutting machine to another line. Or the changeover starts later because the setters are not ready with their other work yet. As a solution he mentioned that people other than the setters are capable of doing the first few steps of the changeover process.

Team Lead Setters

The first problem that is mentioned by the team leader is that the number of minor malfunctions cause that there is not enough time to do his tasks good. Besides being the team lead of the setters he is also the team lead of production and the company mechanics. During the day he receives a lot of phone calls from operators, setters or mechanics when there are minor problems. To reduce the amount of work of the team leaders another team lead is hired. But according to the team lead of the setters this is not enough. One of the improvements that he mentioned is that the people on the production floor should be trained to solve minor problems by themselves. This causes that the team leaders will receive less calls which give them more time to do their tasks. An important thing that is not done correctly at the moment is the monitoring of the setters. The team leader admitted that there is not enough time to watch all the changeovers to see how the setters are doing.

Another thing that was mentioned is that the changeover processes should become more stable. Currently the changeovers with the more complex profiles could take very long. The more complex profiles are often dealing with strict and tiny margins. When there is something wrong with the profile it could take a while to get the profile within the right margins. A solution given by the team lead to improve the stability was that the process needs to be standardized more. Currently there are too many factors that influence the process.

According to the team leader the team work between departments should improve as well. Currently the setters, operators and company mechanics are focused on their own job. The team lead mentioned that when for instance an operator has nothing to do that it could potentially help a setter or a company mechanic. Right now when the operator has nothing to do it will most likely sit back and wait for the next task. Another reason why it is important that the departments start working together is that the capacity of the workforce is very low. When other departments are able to take over minor tasks when they have spare time it could improve the production flow as well.

When the team leader got asked if there is the possibility for the setters to give improvements, he said that everyone can come to him to give improvements. There are not many setters that come to the team leader to give big improvements. According to the team leader are the improvements discussed during meetings with the setters. This contradicts the statements of multiple setters that mentioned that felt like nothing was done with the improvements they give to the team leaders.

Manager Production

The production manager has a big interest in the OEE. According to the production manager everyone carries out their own responsibility in the improvement of the OEE. He knows that there are a lot of things that still can be improved regarding the changeover process. The biggest problem related to the changeover time according to the production manager is with changeovers that take longer than eight hours and need to be handed over another person. According to the manager, the setter in the next shift will have problems knowing with what the setter before him has done.

Another thing he mentioned was that the organisation of the whole changeover process should improve as well. Currently there are too much moments when the machine is standing still for no reason. Team leaders do not have enough time to do their own jobs

Manager Technical Support

According to the Technical Support Manager the biggest problems regarding the changeover time are related to the organisation of the process. Setters are moved to another mill to solve malfunctions during the changeover, tools are not prepared with a checklist, setters are not starting with the changeover when they are supposed to. Steps that need to be performed are documented but no one follows these steps exactly. If there is something wrong with the changeover notes are made and can be used for the next time, but most of the time the notes are unclear and not useful.

Another thing where the manager thinks that a lot of time can be gained is the fine tuning process. Currently the stands are setup by the feeling of a setter. The manager mentions that in the past there were projects to visualize setting up the stands to remove some of the work where “feeling” is needed. This project did not worked out due to resistance from some of the setters and the costs of implementing the new solution. The setters were resisting because setting up the stands with “feeling” was something what made the job fun and interesting.

The final thing the manager mentioned was that setters are searching for tools while there are predetermined spaces for the tools. According to the manager one of the reasons that a setter has to search for tools is the use of the tool cart. Every setter has their personal tool cart with their own tools. But sometimes setters are putting tools from the machine or someone else in their cart. This way other setters do not know where the tools are and time is wasted searching for tools.

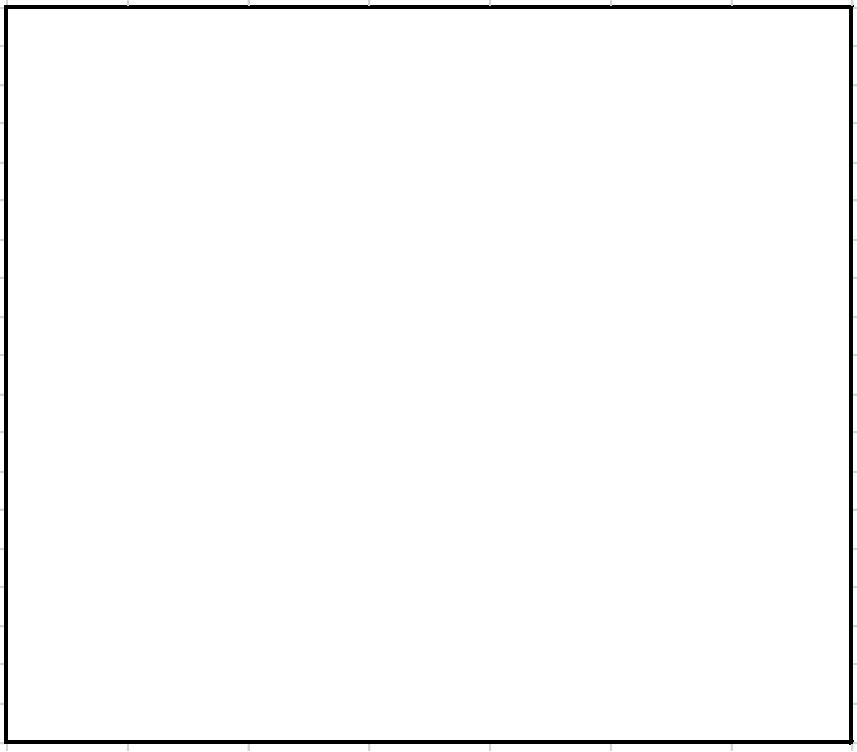
Appendix G Activity Lists Used for Changeover

This section shows the list that was used for the observations. The next will show the empty list that was used during the observations. After that, the filled in lists from the observation are shown with the colour coding that corresponds to the column charts in chapter 4.2 and chapter 6.

Empty List (Example)

Activity	Duration

Note:



List for Observation 1.1

Activity	Duration	
No one working on changeover	08:57:00	00:14:00
	09:11:00	
Looking at drawing	09:11:00	00:01:00
	09:12:00	
Away from machine	09:12:00	00:01:00
	09:13:00	
Looking at drawing	09:13:00	00:02:00
	09:15:00	
Talking with colleague	09:15:00	00:02:00
	09:17:00	
Detaching the cassettes	09:17:00	00:09:00
	09:26:00	
Away from Mill	09:26:00	00:03:00
	09:29:00	
1st cassette from the mill	09:29:00	00:01:00
	09:30:00	
break	09:30:00	00:15:00
	09:45:00	
Meeting	09:45:00	00:37:00
	10:22:00	
getting something to drink	10:22:00	00:02:00

	10:24:00	
Continue with 1st cassette	10:24:00	00:05:00
	10:29:00	
2nd cassette from the mill	10:29:00	00:02:00
	10:31:00	
3rd cassette from the mill	10:31:00	00:02:00
	10:33:00	
1st cassette on the mill	10:33:00	00:05:00
	10:38:00	
2nd cassette on the mill	10:38:00	00:05:00
	10:43:00	
4th cassette from the mill	10:43:00	00:05:00
	10:48:00	
5th cassette from the mill	10:48:00	00:02:00
	10:50:00	
6th cassette from the mill	10:50:00	00:03:00
	10:53:00	
Away from mill	10:53:00	00:02:00
	10:55:00	
cleaning sprayer	10:55:00	00:01:00
	10:56:00	
Away from mill	10:56:00	00:03:00
	10:59:00	
Away from mill	10:59:00	00:00:00
	10:59:00	
Moving the richtstand	10:59:00	00:02:00
	11:01:00	
7th cassette from the mill	11:01:00	00:02:00
	11:03:00	
cleaning the mill	11:03:00	00:10:00
	11:13:00	
asking something	11:13:00	00:02:00
	11:15:00	
Away from machine	11:15:00	00:02:00
	11:17:00	
Attaching cassettes	11:17:00	00:02:00
	11:19:00	
Cleaning tools	11:19:00	00:01:00
	11:20:00	
Driving away first kart with cassettes	11:20:00	00:02:00
	11:22:00	
Driving away second kart with cassettes	11:22:00	00:02:00
	11:24:00	
Driving away third kart with cassettes	11:24:00	00:02:00

	11:26:00	
Driving away fourth kart with cassettes	11:26:00	00:02:00
	11:28:00	
Cleaning	11:28:00	00:04:00
	11:32:00	
Setting the machine	11:32:00	00:05:00
	11:37:00	
Away from machine	11:37:00	00:02:00
	11:39:00	
Attaching "Filt rollen"	11:39:00	00:01:00
	11:40:00	
Moving oil stand and away from mill	11:40:00	00:05:00
	11:45:00	
Away from mill	11:45:00	00:01:00
	11:46:00	
Testing the pulses	11:46:00	00:03:00
	11:49:00	

- Not all the tools are ready at the designated place.
- Company mechanic is leaving while he potentially could start the changeover.
- The mill is a mess, bolts and dirty towels are laying everywhere.
- No crane available

List for Observation 1.2

Activity	Duration	
Cleaning the mill	11:03:00	00:05:00
	11:08:00	
getting crane	11:08:00	00:02:00
	11:10:00	
talking to operator	11:10:00	00:02:00
	11:12:00	
examining the mill	11:12:00	00:01:00
	11:13:00	
away from the mill	11:13:00	00:02:00
	11:15:00	
Getting explanation from another setter	11:15:00	00:01:00
	11:16:00	
Unscrewing bolts	11:16:00	00:02:00
	11:18:00	
Moving a stand to a better location	11:18:00	00:05:00
	11:23:00	
Moving cassette with oil stand to front of the line	11:23:00	00:08:00
	11:31:00	

1st cassette on the machine	11:31:00	00:04:00
	11:35:00	
Applying the 1st cassette to the mill	11:35:00	00:01:00
	11:36:00	
BM needs crane	11:36:00	00:06:00
	11:42:00	
2nd cassette on the mill	11:42:00	00:03:00
	11:45:00	
Applying the 2nd cassette on the mill	11:45:00	00:02:00
	11:47:00	
3rd cassette on the mill	11:47:00	00:03:00
	11:50:00	
Applying the 3rd cassette on the mill	11:50:00	00:05:00
	11:55:00	
4th cassette on the mill	11:55:00	00:03:00
	11:58:00	
Applying the 4th cassette on the mill	11:58:00	00:03:00
	12:01:00	
1st cassette off the mill	12:01:00	00:03:00
	12:04:00	
	12:04:00	00:03:00
unscrewing bolts 2nd cassette and "richtstand"	12:07:00	
2nd cassette from the mill	12:07:00	00:02:00
	12:09:00	
5th cassette on the mill	12:09:00	00:03:00
	12:12:00	
Applying the 5th cassette on the mill	12:12:00	00:03:00
	12:15:00	
6th cassette on the mill	12:15:00	00:03:00
	12:18:00	
Applying the 6th cassette on the mill	12:18:00	00:02:00
	12:20:00	
Getting batteries	12:20:00	00:02:00
	12:22:00	
7th cassette on the mill	12:22:00	00:03:00
	12:25:00	
Applying the 7th cassette on the mill	12:25:00	00:03:00
	12:28:00	
8th cassette on the mill	12:28:00	00:05:00
	12:33:00	
Applying the 8th cassette on the mill	12:33:00	00:04:00
	12:37:00	
getting kart for "richtstand"	12:37:00	00:01:00
	12:38:00	

"Richtstand wegrijden en nieuwe pakken"	12:38:00 12:41:00	00:03:00
Moving "richtstand"	12:41:00 12:42:00	00:01:00
Drinking coffee and checking everything	12:42:00 12:44:00	00:02:00

- When cassettes were put on the machine underneath the cassettes was cleaned.
- Could have been done with 2 people instead of one. The other one could already clean the mill

List for Observation 1.3

Activity	Duration	
Pulling the metal out of the rollers	14:00:00	00:03:00
	14:03:00	
Away from machine	14:03:00	00:02:00
	14:05:00	
Looking at drawing	14:05:00	00:03:00
	14:08:00	
Away from machine --> getting tool kart	14:08:00	00:02:00
	14:10:00	
Talking with another setter	14:10:00	00:02:00
	14:12:00	
Unscrewing bolts from the MT	14:12:00	00:04:00
	14:16:00	
Unscrewing bolts spray stand of the mill	14:16:00	00:02:00
	14:18:00	
Unscrewing bolts frontside of thirteen stands	14:18:00	00:05:00
	14:23:00	
Tidy the lose bolts	14:23:00	00:01:00
	14:24:00	
Unscrewing bolts frontside of the other six stands	14:24:00	00:03:00
	14:27:00	
Unscrewing the backside of seven stands	14:27:00	00:06:00
	14:33:00	
Moving the first two stands	14:33:00	00:02:00
	14:35:00	
Away from machine --> Getting pallet for old stands	14:35:00	00:03:00
	14:38:00	
Placing seven stands on the pallet	14:38:00	00:02:00
	14:40:00	
Putting pallet back in repository	14:40:00	00:02:00
	14:42:00	
Getting new palette	14:42:00	00:02:00
	14:44:00	
Putting seven stands on the pallet	14:44:00	00:05:00
	14:49:00	
Putting the pallet back in repository	14:49:00	00:02:00
	14:51:00	
Getting new pallet	14:51:00	00:01:00
	14:52:00	
Putting MTs on the pallet	14:52:00	00:03:00
	14:55:00	

Placing the MT's back in repository	14:55:00 15:01:00	00:06:00
Getting new pallet	15:01:00 15:02:00	00:01:00
Putting 5 stands on the pallet	15:02:00 15:03:00	00:01:00
Short talk with another setter about what to do	15:03:00 15:04:00	00:01:00
Resuming putting stands on the pallet	15:04:00 15:05:00	00:01:00
placing the stands back in repository	15:05:00 15:08:00	00:03:00
looking at drawing	15:08:00 15:09:00	00:01:00
Toilet break	15:09:00 15:11:00	00:02:00
Placing first stands on the mill	15:11:00 15:14:00	00:03:00
Looking at drawing	15:14:00 15:17:00	00:03:00
Resuming placing the first stands on the mill	15:17:00 15:20:00	00:03:00
Placing empty pallet back in repository	15:20:00 15:22:00	00:02:00
getting new stands	15:22:00 15:23:00	00:01:00
Placing the stands on the machine	15:23:00 15:28:00	00:05:00
Placing empty pallet back in repository	15:28:00 15:29:00	00:01:00
Placing new stands on the mill --> Last stand took longer than usual	15:29:00 15:42:00	00:13:00
Putting empty pallet back in repository	15:42:00 15:44:00	00:02:00
Away from machine	15:44:00 15:47:00	00:03:00
Last stand on the machine	15:47:00 15:49:00	00:02:00
Away from machine	15:49:00 15:53:00	00:04:00
Checking on the "Richtstand"	15:53:00 15:54:00	00:01:00
Away from machine	15:54:00 16:01:00	00:07:00

Moving the Oil cassette	16:01:00 16:04:00	00:03:00
looking at drawing	16:04:00 16:08:00	00:04:00
Setting the pulses	16:08:00 16:12:00	00:04:00
Talking with the team lead	16:12:00 16:14:00	00:02:00
Putting the bolts in the stand	16:14:00 16:17:00	00:03:00

- Mill without cassette.
- An hour in advance there were no preparations or whatsoever for the changeover.
- The changeover was performed with 2 people

List for Observation 1.4

Activity	Duration	
Away from mill --> getting tool kart	13:50:00 13:52:00	00:02:00
Looking at drawing	13:52:00 13:56:00	00:04:00
unscrewing bolts from stands and MT	13:56:00 14:03:00	00:07:00
Tidy up the bolts from the mill	14:03:00 14:13:00	00:10:00
detaching stands from the mill	14:13:00 14:14:00	00:01:00
Getting empty pallet	14:14:00 14:16:00	00:02:00
Putting stands on pallet	14:16:00 14:19:00	00:03:00
Putting stands back in repository	14:19:00 14:21:00	00:02:00
Getting empty pallet	14:21:00 14:23:00	00:02:00
Putting stands on pallet	14:23:00 14:25:00	00:02:00
Putting stands in repository	14:25:00 14:27:00	00:02:00
Getting empty pallet	14:27:00 14:30:00	00:03:00
Putting stands on pallet	14:30:00 14:32:00	00:02:00

Putting stands in repository	14:32:00 14:34:00	00:02:00
Getting empty pallet	14:34:00 14:37:00	00:03:00
Putting stands on pallet	14:37:00 14:39:00	00:02:00
Putting stands in repository	14:39:00 14:42:00	00:03:00
Getting empty pallet	14:42:00 14:45:00	00:03:00
Putting MTs on pallet	14:45:00 14:50:00	00:05:00
Getting new stands	14:50:00 14:52:00	00:02:00
cleaning	14:52:00 14:56:00	00:04:00
Preparing the mill	14:56:00 15:01:00	00:05:00
Away from mill --> getting forklift	15:01:00 15:03:00	00:02:00
Putting stands on mill	15:03:00 15:07:00	00:04:00
Coffee break	15:07:00 15:17:00	00:10:00
Attaching first 7 stands with bolts	15:17:00 15:20:00	00:03:00
Getting new stands	15:20:00 15:23:00	00:03:00
Putting stands on the mill	15:23:00 15:25:00	00:02:00
Getting new stands	15:25:00 15:29:00	00:04:00
Putting stands on the mill	15:29:00 15:31:00	00:02:00
Putting empty pallet in repository	15:31:00 15:32:00	00:01:00
Getting new MT's en "richtstand"	15:32:00 15:34:00	00:02:00
Attaching stands to mill with bolts	15:34:00 16:07:00	00:33:00
Away from machine	16:07:00 16:11:00	00:04:00
Placing MTs on the mill	16:11:00 16:13:00	00:02:00

Putting empty pallet in repository	16:13:00	00:02:00
	16:15:00	
Attach first MT to machine	16:15:00	00:07:00
	16:22:00	
Away from machine	16:22:00	00:05:00
	16:27:00	
Attach second MT to mill	16:27:00	00:04:00
	16:31:00	
Attach "richtstand to mill"	16:31:00	00:02:00
	16:33:00	
Checking everything	16:33:00	00:02:00
	16:35:00	

List for Observation 1.5

Activity	Duration	
Unscrewing bolts frontside	08:46:00	00:03:00
	08:49:00	
Talking with colleague	08:49:00	00:00:30
	08:49:30	
Tidy up pieces between stands	08:49:30	00:00:30
	08:50:00	
Change settings of pc	08:50:00	00:01:00
	08:51:00	
Unscrewing backside bolts	08:51:00	00:04:00
	08:55:00	
Tidy the bolts	08:55:00	00:04:00
	08:59:00	
Moving Mt and sprayer between stands	08:59:00	00:02:00
	09:01:00	
Loosen joints and moving stands forwards	09:01:00	00:02:00
	09:03:00	
Putting plates on the stands	09:03:00	00:01:00
	09:04:00	
Talking with colleague	09:04:00	00:03:00
	09:07:00	
Stands on pallet	09:07:00	00:01:00
	09:08:00	
Clean mill	09:08:00	00:01:00
	09:09:00	

Putting stands in repository	09:10:00 09:13:00	00:03:00
Meeting	09:13:00 09:30:00	00:17:00
Break	09:30:00 10:00:00	00:30:00
meeting	10:00:00 10:10:00	00:10:00
Stands on mill	10:10:00 10:11:00	00:01:00
Stands on pallet	10:11:00 10:12:00	00:01:00
Putting them back in repository	10:12:00 10:17:00	00:05:00
Stand on mill	10:17:00 10:18:00	00:01:00
Stan on pallet	10:18:00 10:19:00	00:01:00
Putting them back in repository	10:19:00 10:22:00	00:03:00
Stand on mill	10:22:00 10:23:00	00:01:00
Stand on pallet	10:23:00 10:24:00	00:01:00
Putting them in repository	10:24:00 10:26:00	00:02:00
Attaching joints to stands	10:26:00 10:27:00	00:01:00
Looking at pc	10:27:00 10:29:00	00:02:00
Attaching joints	10:29:00 10:39:00	00:10:00
Attaching stands to machine	10:39:00 10:52:00	00:13:00
Mt on mill	10:52:00 10:53:00	00:01:00
Attaching MT	10:53:00 10:56:00	00:03:00
Attach piece between stand to mill	10:56:00 10:57:00	00:01:00