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EXTRUSION TOOL MANAGEMENT

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Tämän opinnäytetyön tavoitteena oli selvittää, miten parantaa ekstruusiotyökalujen hallintaa Primo Finland Oy:ssä. Tavoitteena oli selvittää, miten uusien työkalujen käyttöönotto saataisiin toimivaksi, miten työkalun kyvykkyyden säilyminen läpi sen elinkaaren varmistetaan sekä miten työkalun parantaminen ja uusiminen saadaan toimivaksi prosessiksi. Lisäksi tarkoituksena oli vertailuanalysoida (benchmark) muita Primo-konsernin tehtaita ja selvittää, löytyykö heiltä toimintatapoja, joita voisimme hyödyntää Vaasassa.

Työn teoriaosuudessa tutustutaan muoviekstruusioon, muoviraaka-aineisiin sekä Lean-työkaluihin. Teoriaosuuden aineistona käytettiin kirjallisuutta muovituotteiden valmistuksesta, Lean-kirjallisuutta sekä verkkolähteitä. Työ alkoi nykytilanteen selvityksellä, jonka tekemiseen käytettiin haastatteluja. Haastatteluja tehtiin sekä Vaasassa, että myös Primon muiden maiden tehtaiden, Ruotsin, Tanskan ja Puolan kanssa Teamsin välityksellä.

Opinnäytetyön tuloksena saatiin selville useita kehityskohteita tutkimuksen kohteena olleista prosesseista. Kyseisiä prosesseja voidaan parhaiten parantaa ja tehostaa kehittämällä niihin tarpeenmukaiset standardit. Muiden tehtaiden haastattelujen perusteella selvisi, ettei mitään valmiita ratkaisuja tule löytymään. Haastatteluissa kuitenkin selvisi asioita, joita voimme yrittää ratkaista yhdessä.

Avainsanat Lean, ekstruusio, PVC, 5S, TPM

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ABSTRACT

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The purpose for this thesis was to find a way how to improve the tool handling at Primo Finland Oy. The objective was to find out how to improve the deployment of new tools, how to maintain the capability of a tool over the whole lifecycle of the product and how to make the tool improvement and renewal process more effective. The purpose was also to benchmark other Primo factories and to find out, if they have any methods that could be used at Vaasa.

In the theory part of this thesis the focus is on plastic extrusion, plastic raw-materials and Lean tools. The literature and network sources used in the theory part were about plastic manufacturing and Lean. The thesis started with a review of the current state, which was done with interviews. The interviews were done in Primo Vaasa and with Primo factories from Sweden, Denmark and Poland via Teams.

As a result, several targets for development were discovered from the processes under study. The processes in question can be improved and made more efficient by developing necessary standards. From the interviews with the other factories, it became clear that no ready-made solutions were going to be found. However, the interviews revealed issues that we can try to resolve together.

Keywords Lean, extrusion, PVC, 5S, TPM

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LIST OF ABBREVIATIONS

PVC	Polyvinyl chloride
ABS	Acrylonitrile butadiene styrene
PP	Polypropylene
PE	Polyethylene
PC	Polycarbonate
ERP	Enterprise resource planning
IFS	ERP solution by IFS

1 INTRODUCTION

The purpose of this thesis is to improve the extrusion tool handling at Primo Finland Oy. The company produces plastic profiles and pipes for domestic use and export by using extrusion technic.

A die and a calibration are used in plastic extrusion, which comprise one entity. That is one of the four main components of plastic extrusion along with the extruder screws, raw material, and the parameters of the process.

The reason for this research is that the customers' demands set for the profiles in terms of quality and delivery times are high and there is increasing competition in the industry. This also raises the requirements for the tools.

1.1 Objectives of the Study

The thesis has three objectives: to research the current situation of our tool handling process, benchmark the corporation's other factories and make suggestions for development.

The objective of the theoretical part of the thesis is to give background information about the process related to this study. The theoretical part consists of the theories of extrusion and LEAN.

The research problems consists of the following questions:

- How to make receiving of new tools more effective?
- How to ensure that the capability of a tool remains over the whole lifecycle of the profile?
- How to make the tool improvement and renewal process more effective?

The focus of the research is on maintaining the usability and capability of a tool, how a tool should be maintained so that it can be used to produce profiles that keep up with the strict quality criteria over the product's entire lifecycle. From the entire tool process view, also the deployment of a new tool and the improvement of a tool will be reviewed.

1.2 Research Methods and Material

This thesis is a qualitative study. The theoretical study of this study consists of the theory of extrusion, raw materials and the theory of Lean and Lean tools relevant to this study. The object of the theoretical framework is to explain the theories behind this thesis.

The research of the current state was done using semi-structured interviews. A semi-structured interview is done by asking the same, or almost the same questions in the same order. By some definitions the order of the questions can differ. There is no uniform definition of how a semi-structured interview should be done. (Hirsijärvi & Hurme 2001, 47.)

The interviews were done 5–7. April 2022 via Teams with:

- Sweden, Limmared
    - Supply Chain Manager
    - Technical Manager
- Denmark, Tistrup
    - Production Manager
    - Production Supervisor
- Poland, Zory
    - Technical Director
- Finland, Vaasa
    - Project manager

In addition, interviews were conducted with operators at Vaasa.

2 INTER PRIMO A/S

This thesis was done for Primo Finland Oy, which is a part of Inter Primo Group. Inter Primo Group is an industry leader, and it employs over 1000 people in thirteen locations in nine countries. The locations are as illustrated in Figure 1. (Primo)

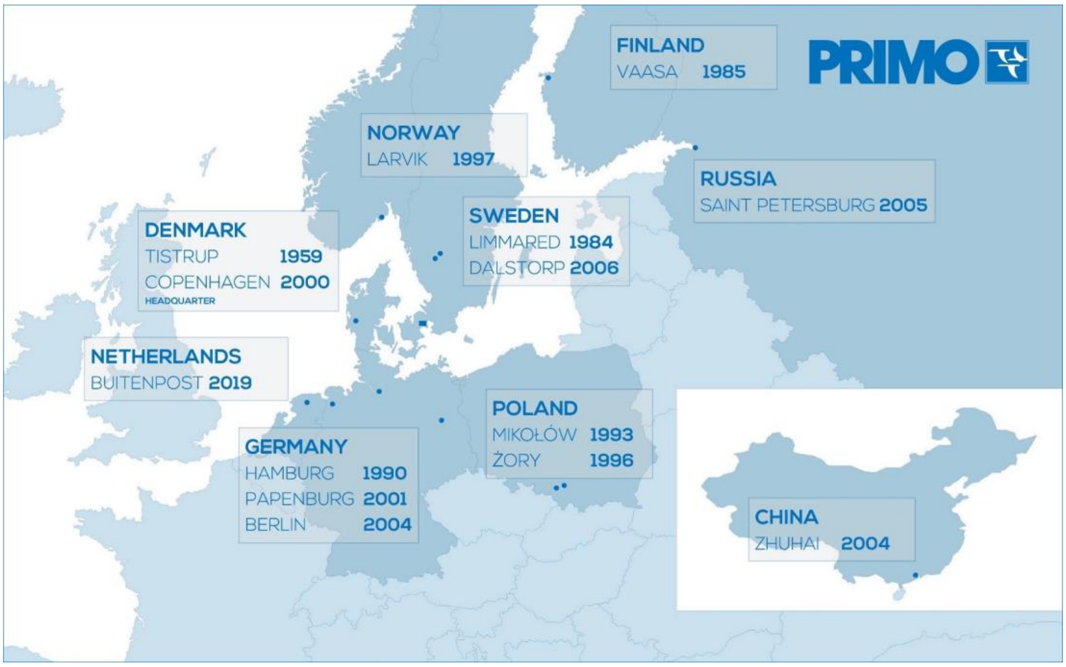

Figure 1. Inter Primo subsidiaries. (Primo)

Primo was founded 1959 in Tistrup in Denmark. The family-owned company headquarters is in Copenhagen. Primo's line of business is producing extruded profiles from plastic, rubber, and composite materials. The turnover of the company was 144 million euros in 2020. (Primo)

Inter Primo bought WH-Profil at Vaasa in 1985 and renamed the company Primo Finland. Today Primo Finland employs 71 people and the turnover was 21 million euros in 2021. The main customer industry areas are:

- Building
- Lightning

- Energy
- Door- and window
- Refrigeration, Heat, Ventilation and Air-conditioning
- Transport
- Marine
- Greenhouse
- Bio- and composite products

Primo is set to move to a new location in Runsor later this year. This makes a large-scale expansion and faster production lines possible, as well as creates an opportunity to take in use Lean and 5S. (Primo)

3 EXTRUSION

Extrusion is a method for continuous process used to produce plastics. The raw material is transferred into the hopper on top of the extruder. From there it is then fed to the screws. The molten plastic, or extrudate, is pushed through the die. After exiting the die the molten plastic is pulled using the haul off machine and cooled in the calibrator and cooling tank. After the haul off, the profile is cut into desired length and then transferred to the packing table as illustrated in Figure 2.

Two types of extruders are used in extrusion, a single-screw extruder or a dual-screw extruder. Inside the extruder, in the barrel, the revolving screw melts the plastic with the help of pressure, friction and with heat from the barrel wall. The gap between the barrel and the thread of the screw decreases and increases the pressure for the molten plastic. The increase of the screw's rpm adds friction on the molten plastic. The barrel is heated with heating elements and by adjusting the temperature of the elements, the amount of heat conducted can be altered. The type of extrusion is defined by what happens in the die and after that. (Järvinen 2017, 154.) This study is about profile and pipe extrusion.

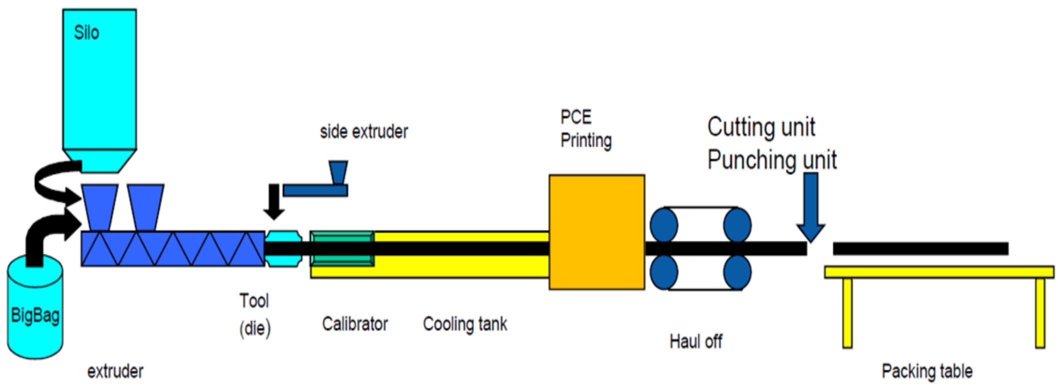

Figure 2. Example of a profile extrusion line. (Primo)

3.1 Raw Materials

The start of modern plastics industry began 1907 when the first synthetic plastic, Bakelite, was developed. Modern mass consumption plastics polyethylenes (PE) and polyvinyl chlorides (PVC) industrial production was developed in the 1930's and polypropylenes (PP) and polystyrenes (PS) in the 1950's. (Plasthouse)

Plastic is a generic term for many distinct types of polymeric materials, which differ in properties (Muoviteollisuus ry). Plastics can be divided in many ways. With their chemical origin in inorganic or organic plastics, based on their plasticity in thermoset or thermoplastic and most commonly by their price and performance as illustrated in figure 4. 80% of all plastic consumed in the world consist of mass consumption plastics. (Plasthouse)

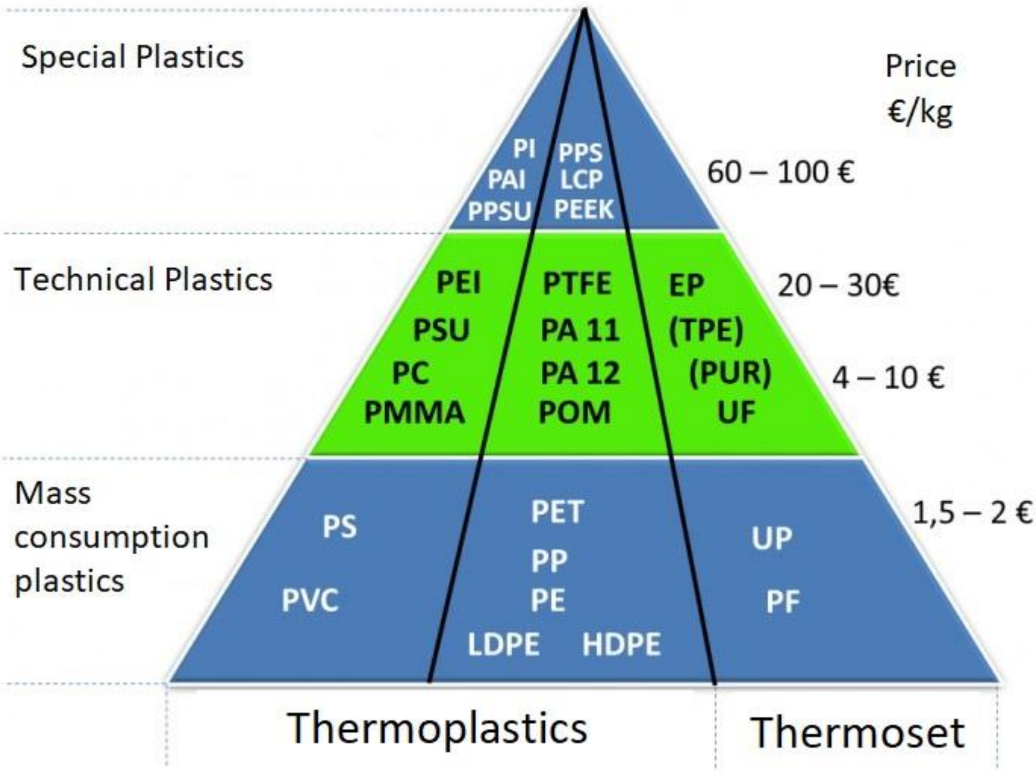

Figure 3. Division of plastics. (Muoviteollisuus ry (modified))

The most important raw material in plastic is oil. 4–6% of the worlds crude oil production is used to produce plastics. Plastic can also be produced out of renewable sources; bio-based plastics use milk, corn, sugar, and rapeseed oil as raw material. (Plasthouse)

Plastic usually contains additives to improve the properties, not just polymers. Common additives include plasticizers, stabilizers, fillers, antistatic agents, lubricants, and dyes. (Plasthouse)

PVC is the most used material at Primo. Figure 4 illustrates the material usage from last year. Almost 94 percent of the plastic usage was PVC. The remaining 6 percent consist mainly of technical plastics, with the four most used being ABS, PP, PC-ABS and PE.

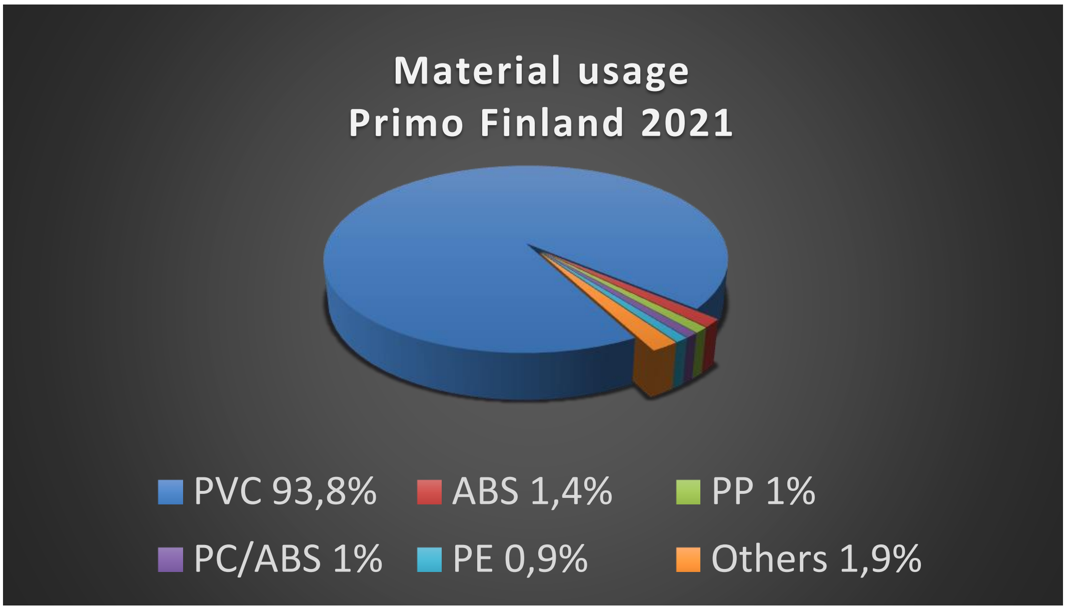

Figure 4. Material usage year 2021 at Primo Finland.

4 LEAN

The Lean production philosophy is based on a production system developed by Toyota almost a hundred years ago. Lean main principal is that instead of focusing on small details, the focus is on optimizing the whole. The object of Lean is to maximize flow efficiency and resource efficiency. Flow efficiency is the ratio between lead time and value-added time. Lead time is the time it takes to perform a job. Lead time consist of value-added time and non-value-added time. Value added time is things that the customer is prepared to pay for. As the lead time grows, resources are used on other things than creating value to the customer. When resources are used on non-value-adding work, the productivity drops. Therefore, the main object in Lean is to minimize the lead time. (Leanin historia)

Lean includes many tools, theories, and concepts, but it is often misunderstood that the tools itself will solve all problems. On the contrary, the tools and concepts are used by the personnel to find the problems in the process. The management must then have enough knowhow to solve these problems. Instead of just focusing on these tools, it will be much more useful to focus on the thinking- and behavior-patterns of continuous improvement and adaptation. The typical way is to improve if there is time for that. At Toyota improvement proceeds production. (Mitä Lean on?)

4.1 Lean tools

Lean has developed many tools over its history, tools that are used to identify and minimize waste in the process. The main tools are seen in Figure 3.

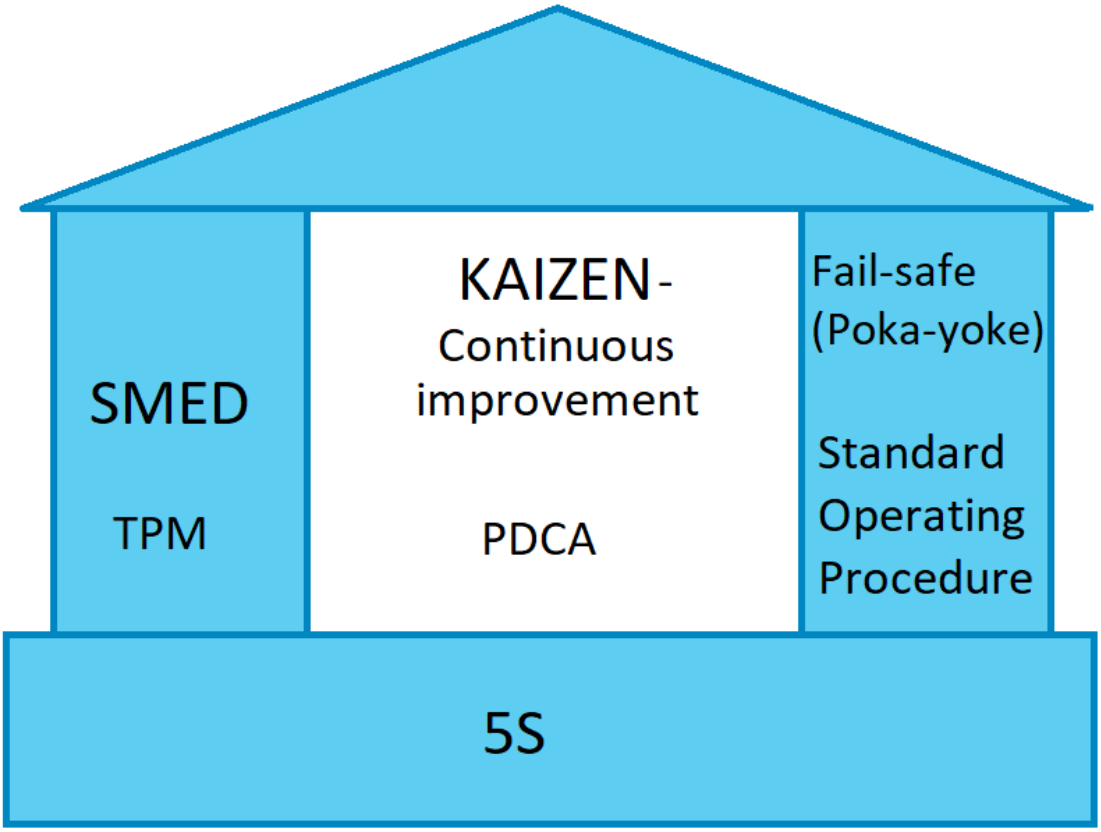

Figure 5. House of Lean.

4.2 5S/6S

One of the Lean tools is 5S. It is a tool to organize and standardize work methods. 5S comes from the five steps of a workplace organization process. The original Japanese steps are:

1. Seiri (Sort)
2. Seiton (Straighten, Set)
3. Seiso (Shine, Sweep)
4. Seiketsu (Standardize)
5. Shitsuke (Sustain)

Later a sixth step, safety first, was added. 6S is often thought of as the foundation for continuous improvement. (Isixsigma)

The main objective for 6S is to enhance efficiency, effectiveness and safety through organization and standardization. To do that, everything must have its own place and be stored in that place. By keeping the workplace clean and organized no time is wasted on searching.

4.3 SMED

SMED (Single-Minute Exchange of Die) is a method for reducing setup time. Setup time is divided into external and internal. Internal setup can only be performed when the machine is not running, external setup when the machine is running. (Leanproduction)

The key thing is to convert as many of the internal setup steps to external, and to simplify the remaining steps. The goal is to reduce the changeover times to 9 minutes or less, single-digit minutes. (Leanproduction)

Shigeo Shingo first developed the process to minimize set-up time of pressing machines. The eight techniques that should be used in implemented SMED, according to Shingo are:

- Separating internal and external setup
- Convert internal setup to external
- Standardize function, not shape
- Use functional clamps or eliminate fasteners altogether
- Use intermediate jigs
- Adopt parallel operations
- Eliminate adjustments
- Mechanization (Lean six sigma definition)

Reduction on the amount of time used in change overs increases flexibility and production time which leads to higher productivity.

4.4 Poka-yoke

The term Poka-Yoke means mistake-proofing and its aim is making mistakes impossible. In a process or a product, these techniques can improve the quality and reliability. (Kanbanize)

The goal is to reduce human errors whenever they are possible. The three most common types of causes, which lead to mistakes are:

- Faulty memory can cause a person to forget important steps such as:
    - During assembly forget to insert a part.
    - To miss a process step such as removing a part or recording measurements.
- Wrong perception can lead to errors such as using incorrect part or material quantities.
- Incorrect execution can lead to errors in setting up the machine or jigs correctly, performing required steps in a wrong sequence, incorrectly measuring part dimensions, or even using wrong parts in the process. (Fractory)

Figure 6. Poka-Yoke. (Fractory)

4.5 Total Productive Maintenance

TPM (Total Productive Maintenance) is a systematical method to develop, together with the operators, a production with no breakdowns to lower the costs and raise the efficiency of the process. (Tuominen. 2010, 8)

The TPM model consists of a 5S foundation and eight supporting pillars which are:

- Autonomous maintenance
- Planned maintenance
- Quality maintenance
- Focused improvement
- Early equipment management
- Training and education
- Safety, health, environment
- TPM in administration

Autonomous maintenance means that the operators themselves do routine maintenance, such as cleaning and inspection. (Leanproduction)

4.6 Standard Operating Procedure

SOP – Standard operating procedure is a written set of instructions which is a detailed briefing of a routine or a step-by-step activity. It is to help in executing daily tasks, maintenance, security procedures, calibration and use of equipment and many other applications. Each application requires the development of its own SOP. (Think lean six sigma)

The procedure should be implemented exactly as the standard says, no deviations or modifications, to guarantee the expected outcome. All deviations and modifications should be investigated and documented in an internal deviation procedure. (SOP)

4.7 Continuous Improvement

Continuous improvement, also known as Kaizen, is a never-ending strive for perfection. It is to improve every process by increasing all the operations that creates value to your customer and removing as many waste activities as possible. (Kanbanize)

There are three major approaches for achieving continuous improvement. The Plan-Do-Check-Act, Root Cause Analysis (RCA) and the Kanban system. The PDCA cycle, as illustrated in Figure 7, is a simple method for continually improving products, people and services. It is an essential part of Lean management. The four stages are:

- Plan – What is the core problem, what is the best solution for fixing it and in what conditions will the plan be successful?
- Do – Acting with the plan and applying everything that was considered in the planning-stage.
- Check – Auditing the plan’s execution and see if the initial plan worked. Identifying the problems of the process and eliminate them. If something went wrong, finding out the root cause. This is the most important stage of the cycle.
- Act – If all the objectives were met, the initial plan can be applied, acted. The PDCA model will become the new standard baseline. (Kanbanize)

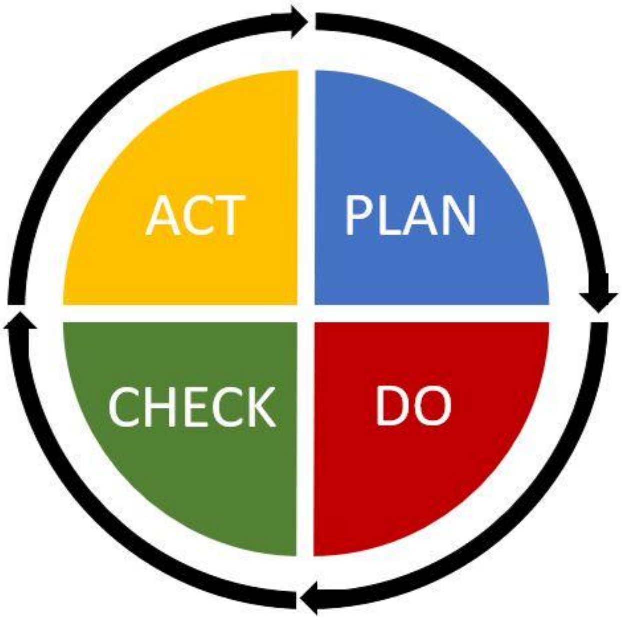

Figure 7. The PDCA-cycle.

5 DEPLOYMENT OF A NEW TOOL

When a tool arrives to Vaasa from the Netherlands, it is transferred to the tool shop. There it is opened and checked that all the required parts are included. The package contains a picture of what should be inside. The parts are then roughly checked to see if the grooves and diameters match. Sometimes there have been tools, which do not fit the existing adapters or the latest was, that the form pieces used in the vacuum tank were too wide and did not match the tank. This shows that the manufacturer should be asked to send order confirmation and it should be checked even before they start manufacturing it.

There is a process description for order- and delivery processes and for ordering a tool, but it has not been updated since the tool manufacturing was transferred to Primo Tools in the Netherlands. The process lacks standardization and there is no assigned person who is responsible for accepting the tools at arrival.

When eventually the tool has been through one or more test runs, it is ready for the first production batch (at times there is no separate test run). Before the first production run, a meeting is held, where the project manager presents the up-coming product to the key people involved:

- Background of the product (purpose of usage, application)
- Things that the customer has brought up about the profile
- Production line and materials to be used
- Accessories needed (cutting, stamp, welding etc.)
- Accepted master sample at display
- Accepted drawing
- Process data from test runs at Primo Tools
- Tool at display (if it has arrived at this point)

On the first production run there is usually someone from the R&D department helping with the setup. If the production succeeds, the tool is accepted. However, there is no statistical analysis on how the first production batches succeed. The amount of time that goes to the running-in of the process and the amount of scrap that is made should be monitored, especially in the beginning. That way the tool could be improved even at the beginning of its lifecycle. The product drawing should be updated after the customer has accepted the samples. A follow-up meeting should be held after the first or second production run, in which there should always be present the operator who was there to produce it.

A good example of this is one profile, which has been in production for about three years and the scrap percent is 30. Since the start of this product, there has been difficulties with it and there are improvements made. The problem is that when an improvement has been made, it stops there. The presumption is that it helped and that it is enough.

In conclusion, the main things to improve in the deployment of a new tool are:

- Creating a Standard operating procedure when the tool is ordered and when it arrives, assigning responsibilities.
- Making a SOP for the acceptance of the tool in the production.
- Making a SOP for updating the product drawing after the customers' acceptance.
- Organizing a follow-up meeting after one or two production runs to further develop the process concerning the tool or anything else in the process.
- Improving the quality control especially on the first production runs. Extra support from the quality technicians and making sure that every-one who is working at the production line knows all requirements.

6 USABILITY AND STORING OF TOOLS

Primo uses mainly three different types of tools, which are flathead, conical or pipe tool. An example of a flathead tool assembly is illustrated in Figure 8. The tools are numbered with a P-number for example P0001. A majority of the tool dies and calibrators are stored in boxes according to that number in numerical order. The tools are also organized by departments. Rigid-PVC tools are in one section of the shelves, foamed PVC tools are in one section etc. The bigger tools and calibrators are stored on the floor underneath the shelves and on a different section in the other end of the building. Pipe tools have their own room in the warehouse.

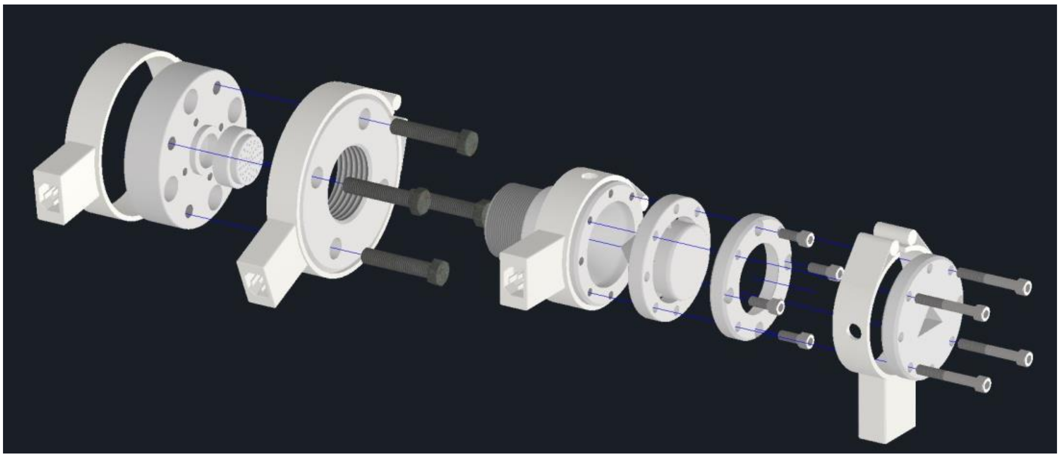

Figure 8. Example of a tool assembly.

Round flathead tools use standard frames which are:

- 100mm
- 125mm
- 156mm
- Foamed PVC tools have a 120mm frame
- Plasticized PVC department uses a 150mm frame

Then there are three different sized square flathead frames:

- 150mm*100mm
- 200mm*100mm
- 245mm*120mm

There is only a finite number of each frame, which means the frames must be stored separately from the dies. Pipe tools consist of a bushing, a cone and frame. Each pipe size has its own bushing and cone but there is only a small number of frames which are used for all pipes.

The conical tools are made with new group standards. They are also designed in a way that, when it is assembled, each plate has screw holes in a different location. That way it is a poka-yoke assembly and it is not possible to assemble it the wrong way. The same technique is used in some older flathead tools if the die consists of more than one plate. The plates are first put together with pins and the pin holes are in different locations in the plates.

The advantages in using a conical tool are:

- It can be stored as a whole. Disassembly is not required after every use, because the parts are not needed with any other tool.
- The manufacturing process is more stable.

The main reason for the use of flathead tools is that they are much cheaper to manufacture and the setup time is faster if you only change the die.

In the storage room there are also bolts of all sizes and heating elements. The bolts are organized in their own boxes according to size and length. The heating elements are stored on a wall according to the diameter.

When an operator needs a tool, he goes to the warehouse and collects the necessary parts including the die, calibrator, frame, bolts, and heating elements by him- or herself. There is a little help from the technical card, an A4 sized folder, which contains information about the product. Usually there is at least the process parameters, temperatures used in the cylinder and tool, machine rpm etc. Sometimes there is information about the tool assembly and even a photo. However, most of the product cards are out of date, so the tool collecting is mostly reliant on the operator's skills.

After the production, the operator usually dissembles the tool and cleans it as much as possible right after the disassembly. With some materials, like Polypropylene or Polyethylene the tool can be removed and stored as one piece without any cleaning. The same method is used with some conical PVC tools, after a cleaning material is run through the tool. After the tool is removed, the operator first removes as much of the material as possible from the tool, when it is still warm and then returns it to the tool cleaning.

6.1 Tool Cleaning

When the tool is brought to cleaning after the production, it is the tool cleaner's job to clean the tool. The cleaning is done manually using a gas flame to burn the material left in the tool. After that, the burnt material residue is cleaned with a sandblasting machine that uses small corn granules. If there is still something left in the tool, it is carefully removed with sanding paper. When the tool is clean, it is oiled and put back in its place in the warehouse.

6.2 Tool Maintenance, Repair, and Improvements

There are different scenarios of where problems are usually found with tools. The first is that during assembling of the tools, the operator discovers that the screw threads are broken. Usually, when this happens the operator makes a fault report using IFS and then brings the tool to the tool shop for repairs.

Another thing that happens is that during running-in the operator notices that there is a scratch on the surface of the profile. This is usually caused by either some scratch or burnt material in the die or scratch or something in the calibrator. If cleaning the calibrator does not remove the scratch from the profile, the operator then dissembles the tool and cleans it. If the cleaning helps, the operator then assembles the tool and tries again. If after the cleaning there is a visible scratch in the tool, the operator should make a report in the IFS and then take the tool and a sample of the profile to the tool shop for repairs.

Yet another scenario is that during running-in, the operator cannot get dimensions of the profile within the tolerances. This is a more complicated problem to solve because there is more than one probable reason for this. This can be caused by damage or wear in the tool, wear in the extruder screws or cylinder, faulty batch of raw material or simply the operator lacks skill. The first thing to do to solve this is usually getting help from the team leader or a more experienced operator. If he or she cannot get the profile in shape, then it is usually the tool or raw material that is faulty. At this point, the operator changes a different batch of raw material to rule that out. Only after that, one can be certain that the cause is the tool. If the tool is the problem, then the operator makes a fault report in IFS and brings the tool and samples of the profile to the tool shop.

Then there are profiles which are simply hard to adjust. There should be an easier, more efficient way to monitor the scrap percentages of products and then a regular method used to improve tools where it is high.

6.3 Tool Renewal

The tool renewal process is a bit complicated. First, it depends on who owns the tool, Primo or if the customer has the right of possession. Secondly, it depends a lot on what kind of tool it is, for example if it is only the die that needs to be replaced, it is much easier. For bigger tools, which are more expensive, or tools that are used rarely, the decision is harder. From the productions point of view, on some cases the renewal decision takes way too long. The same problems are fought with repeatedly until someone finally makes the decision to renew the tool.

7 OTHER PRIMO FACTORIES

A part of this study was to benchmark Primo factories in other countries. An interview request was sent via email to factories in Sweden, Denmark, and Poland. Luckily, everyone replied very soon and accepted. The interviews were done using Microsoft Teams.

The main process, starting from getting the tool from the warehouse to the production line and how it is returned after the production run works almost the same in every factory. They were also facing the same kind of problems as the Vaasa factory.

Tool cleaning is mainly done by hand. It is very laborious and demands a skilled and sharp-eyed cleaner to get the tools thoroughly cleaned. If one is not careful, the tool may be damaged. Some tools have small ducts or chambers which are especially hard to clean manually.

Besides manual cleaning, machines are used to make the cleaning easier. Denmark and Poland use ultrasonic cleaner, but neither factory was content with it. It works well for removing grease and wax from the calibrators, as the one illustrated in Figure 9, but it does not really work for dies with plastic residue.

Sweden uses a high-temperature oven for polyolefin plastic tools. Denmark is also considering buying a similar oven, but to be used with all materials, even PVC. Their plan is to first burn off the plastic left in the tool and then try removing the rest with the ultrasonic cleaner. This acquisition is interesting and should be followed to see if it works. It could help by removing a big part of the manual labor and to protect the tools, when the heating is done in a more controlled way instead of heating it with a gas flame. The oven also distributes the heat more evenly than a flame, so it is less harmful for the tool.

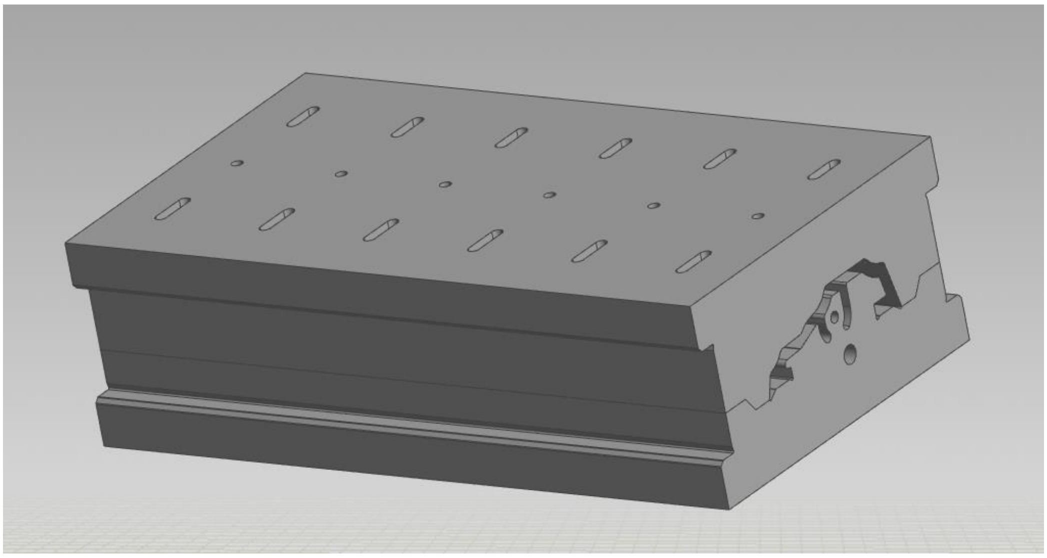

Figure 9. Example of a calibrator.

The Polish factory had an idea about buying a dry ice cleaner. They were convinced that it could work as they had seen it at an exhibition. It is a fast and safe way to clean the surface of the tool without doing any damage. It has been tried out in Finland some years ago and at least that experience showed it did not work. The dry ice did not remove the plastic from the cavities inside the tool.

The Swedish factory had some difficulties in cleaning the tools after foamed PVC and ABS. The tool looked dirty and had a lot of plastic residue. In Finland, if a foamed PVC tool is used for a month without cleaning, it still does not look as dirty. The question was if the tools made from some other type of metal or if there are some differences in the raw material? This is an interesting thing that should be studied more.

The biggest difference when comparing the Finnish factory to the other factories, was the level of organization. The tool shop and the warehouse in Poland and Swe-den was, based on the photographs they showed, very well organized and clean.

8 DEVELOPMENT SUGGESTIONS

This following chapter is based on the information gathered from all the interviews made, from my own experience in the production and from literature about Lean.

8.1 Usability and Storing

The first thing to do, is to get the warehouse organized with the help of 5S. The amount of time wasted in searching tools is minimized if all the tools are in specified places. A problem is that at the current warehouse the space is limited, but the new factory and possible vertical carousel storage will be a solution for the storing problems. To make the vertical storing work, the tools need to be organized differently. Each die should be in a box along with the following things:

- Die
- Calibrator
- Bolts
- Master sample
- A list of everything and a photo

The frames should be according to size along with all the same sized heating elements, torpedos, and all other necessary parts. The bigger calibrators are too big to be stored in the vertical carousel, they should be stored in some other room.

If the vertical carousel solution is not taking place, then the order of the warehouse should be changed from the current one. The problem with storing the tools in order with the P-number is, that sometimes a new tool is numbered between the existing ones and then all the tools have to be moved to get the new one in the correct place. It would be simpler if the shelves would be numbered and there would be a numbered place for each tool or even an electronic catalog to find each tool. Then it would be also easier to move the tool to another location if necessary and it would still be found. This is the way it was done in the Polish factory.

The other tool parts that do not belong to any specific product should be marked to help the identification and to make it easier, especially for new workers, to find the needed parts. Some tests have been made to put a QR- and RFID code on the tool, but that did not stick well enough to last the heating and cleaning of the tool. With the QR-code the tools could have been scanned before each transfer which would have made it possible to record every transfer.

To implement SMED into the tool storaging the tools should be transferred from the warehouse to each line automatically. At the start of each day, the data for each tool needed in the production in the next 24 hours could be transferred from IFS to the person in charge of the transfers. The tools would then be picked from the warehouse and transferred to a specific place at the production line.

Another improvement to cutting on the setup time would be to preheat the tool. Depending on the size of the tool and the required temperatures, the heating takes about 30-90 minutes. To make preheating possible, there should be a place to set the tools beforehand. The downside of this is that when the tool is hot, it is more difficult and riskier regarding safety to attach it to the extruder. The tool should be preassembled and there should be a better way of fixing the tool to a crane to make it easier and safer to attach.

I strongly believe that the new factory layout, which puts all the tools in the same storage will help controlling the tools, as does the joining of the tool cleaning and the tool shop.

8.2 Tool Cleaning

The way to improve the tool cleaning in Finland is to renew the sand blasting machine which is long overdue to be updated. The new oven that the Danish factory is going to invest in, is something that Finland should be following up on. If they find it useful, one should be also bought to Vaasa.

One interesting device that came up in a conversation was a laser cleaning device. It is used usually used to clean impurities, such as rust or paint from a surface. However, it could possibly also be used on cleaning extrusion tools. It is advertised as a fast and effortless way to clean surfaces. This is a method that should be tried.

The relocation of the tool shop and tool cleaning closer together and closer to the production will also improve the communication. The demands for the tools to be clean should be put to the tool cleaner, but also the responsibility to the operator to check the tool more closely before assembling it at the line. There should be a method for reporting each time a tool is not thoroughly cleaned, so that it would be noticed, if the problem occurs with some specific tools more often.

8.3 Tool Maintenance, Repair and Improvements

Each tool should have a limit of inspection depending on the volume of the product. For example, 100 000 meters, where the following things should be checked:

- weight of the profile
- manufacturing speed
- scrap percentage
- time used on setup
- interference sensitivity
- opinion of the tool from the operators

As an example, if a profile is 5 percent overweight because of wear in the tool and the line normally produces 10 000 kilograms in a week, the amount of waste is 500kg which, at 1,5–2€ per kilogram, is 750–1000€ waste in a week.

Of the amount of time saved from not wasted on searching for tools in an unorganized warehouse, the operators could do autonomous maintenance. One thing that comes up quite often is that the screw threads are broken either on a flange of an extruder or a tool frame. It is often caused by using wrong length bolts. This is a problem that could be fixed by training the operators to check the threads periodically and making a standard way of working of it, as well as also training to use bolts of the right length. This way the downtimes would be minimized when the problems are found and fixed in advance.

8.4 Tool Renewal

There are products which are more demanding when it comes to the surface. For example, linear lenses and LED light diffusing profiles are such products. According to the operator on this production line, the problem is very often that the tools have not been thoroughly cleaned. Even the slightest scratch on the tool will be visible on the profile. There is a way to clean it, so that there are no scratches. Using a paste machine, which pushes a diamond paste through the tool is an effective way to clean, but the downside is that it also wears out the tool at the same time. Now the situation is that the tool sometimes goes through the paste machine, but often only after the production has been started and the operator notices scratches on the profile.

A better way would be to inform the customer that the tool needs to be cleaned with the paste machine after every production. The customer could be given an estimate of how many production batches the tool will last, until they must purchase a new one. This way the costly production errors and the downtimes will be minimized. The tool should be designed in a way that the outer plate of the die could be easily replaced with a new one without any need for finishing.

A more effective way to monitor the downtime each tool causes should be developed. The same procedure that should be created to inspect each tool regularly could be used to determine if a tool needs to be renewed.

9 SUMMARY

The objective of this study was to streamline the transfer of the tools from the warehouse to the production line and back to the warehouse after the production. The focus was on maintaining the usability and capability of a tool.

As for streamlining the tool movements, the best way is first to organize them so that collecting tools is easy and fast. Furthermore, tool transfer should be automated. When the tools are properly cleaned and in good condition, the need of transfers back and forth between production and the tool cleaning are minimized. To enable more effective cleaning, the methods of cleaning should be updated. A proper condition of tools also ensures that no delays occur when production is supposed to start and reduces the quality defects on products. An inspection interval should be created to each tool to assess the need for maintenance or renewal.

As a result of this thesis, several targets for development were discovered. As of the research problems, some solutions were found in each that can be implemented to make improvements. Many of the operations needs a Standard operating procedure.

This thesis was particularly challenging because it was research and it was clear from the start that no simple solution would be found. The interviews were interesting and I hope that the collaboration between the factories will continue in the future. Even with my long history at the company, doing this study taught me a lot of new things.

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