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DEVELOPMENT OF MASTERCAM SETUP SHEET TEMPLATES

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<p>The aim of this thesis was to propose development of Mastercam setup sheet templates integrated with Lean principle and Single Minute Exchange of Die (SMED) techniques to optimize machining setup processes. Traditional setup sheets often lack comprehensive information, resulting in inefficiencies and delays during CNC machining operations. By leveraging Lean methodologies and SMED principles, this research presents a refined setup sheet that streamlines setup activities, reduces nonvalue added tasks, and enhances overall productivity. The thesis was commissioned by Camcut Oy.</p> <p>The Mastercam setup sheet is a critical component of the research conducted in the field of computer-aided manufacturing (CAM). The setup sheet serves as a comprehensive guide for the setup and machining of a specific part. The thesis report begins with an overview of the Mastercam software, its features, and its role in computer aided manufacturing. In the study the various elements included in a typical Mastercam setup sheet, such as tool information, holder information etc were explored. In this project a proper setup sheet documentation in enhancing productivity and reducing error during the machining process was found. The effectiveness of different strategies and presenting information on the setup sheet to improve operator understanding and efficiency were investigated.</p> <p>The implementation of the modified Mastercam setup sheet with Lean principles and SMED techniques has the potential to significantly improve manufacturing efficiency, reduce setup time, enhance productivity, and eliminate waste. By fostering a culture of continuous improvement and standardized work, this approach contributes to the overall competitiveness and profitability of manufacturing operations.</p>	
Keywords CNC, CAD, CAM, SMED, XML, Lean Methodology, Setup sheet, machining process, Milling Machine.	

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ABBREVIATIONS

CNC	Computer Numerical Control
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
3D	Three Dimensional
2D	Two Dimensional
XML	Extensible Markup Language
HTML	Hypertext Markup Language
SMED	Single Minute Exchange of Die

1 INTRODUCTION

The manufacturing industries are facing pressure to improve the production efficiency, reduce the cost and increase productivity. Traditional Mastercam setup sheet can be time consuming and inefficient, leading to increased setup time decreased productivity in CNC machining process. This traditional setup sheet information is not organized properly, and many missing information need to be added to fulfil a specific CNC machine set up criteria.

1.1 Commissioner

This thesis was commissioned by Camcut Oy because they want to modify a Mastercam setup sheet according to their requirement. Camcut oy is a Finnish company that helps to precision machining manufacturing of metal components, providing a wide range of machining services to their customer. The company provide machining services by importing the machining product. The company founded in 2014 and located in the Siilinjärvi near the city of Kuopio, Finland. Their provided services related on milling, turning, drilling, and grinding and can complex problem solution related on the machining.

Camcut offer design and engineering services to helps clients optimize their manufacturing processes and improve product quality. Focus of Camcut Oy is to provide top quality machining related services to clients that meet their unique needs and requirements. They import and sell quality product for machining process. They provide Mastercam training, support services, method design and programming, special tool & reconditioning services. They provide technical support and train them in their use. They arrange training program according to their customer need. This company organize trainings with professional trainer who has working experience in workshop and educational training. They continuously try to develop metal industry with help of their expert and offer their customers the latest and most efficient products and solutions for development. They help their customer with CNC programming situations and provide the whole solution by using the best tools, workpiece clamping and machining methods and programming the toolpaths using the most powerful CAM software features. Camcut oy support to develop workshop that increase production efficiency, machinist skills and company profitability. Their goal of business is to find the best and cost-effective solution to their customer need. This company is collaborating with Walter Tools, Fuchs Oil, Mahr, Schussler, SFT Spannsysteme, Dummel Werkzeugfabrik, M.T. S.r. l, Mikron tool, Kemmler, ARIANA-Industrie, SAV, SmiCut, Kroeplin, Kexagon Absolute Arm, ER-EL, Pocket NC, MPA. This company works with various kind of software like Mastercam, CIMCO, Robotmaster, Verisurf. (Camcut, 2023 n.d.)

1.2 Mastercam

Mastercam is world most popular computer aided manufacturing (CAM) software that used in manufacturing industry to create 2D and 3D parts and components for various application. The software provides wide range of features to helps users design, program, and control CNC machines.

Mastercam is popular for its powerful toolpath generation capabilities, user friendly interfaces and simulation features that visualize and test the machining process before starting the actual process. (Mastercam, 2022.)

1.3 Setup sheet

The Mastercam setup sheet is a document that provides a summary of the machining process. The Mastercam setup sheet serves as a valuable reference for the operator, programmers, and machinist involved in the machining process.

Mastercam setup sheet is an important tool for anyone in the manufacturing industry, providing an easy and effective way to organize and present information about their machining process in clear and concise format. Active report is a user-friendly tool that doesn't require programming knowledge. It is included with Mastercam as part of the standard installation and can be easily configured to meet the needs of individual users and organizations. The Active Reports generate data from the Mastercam. Through the Active report tool, a user can extract and analyze data from Mastercam, such as toolpath information, cutting times, materials usages and so on. (Mastercam Help Center, 2022.)

Setup sheets ensure correct tooling to CNC machinists by providing various kinds of information. By providing the information about the tool settings, setup sheets increase efficiency. Setup sheets provide an organized summary of the necessary steps, tools, and parameters required for the job. Setup sheets reduce error and mistakes in every step of the CNC machining process. If there are any changes needed during the milling process, the setup sheet can be used to notify this. This helps the operator to communicate with the designer and with the next step people also. With this communication, getting easier with setup sheets. (CNC Cookbook, n.d.)

1.4 Zenex

Zenex is a Finnish company that is specialized in providing IT services and solutions. Zenex provides services to support business in their technology needs. This includes IT infrastructure management, cloud services, cybersecurity solutions, data management, software development, and IT consulting. One of the main products of this company is Mastercam. Mastercam setup sheet is modified with Active report designer software. Zenex provides instructions and materials for the Active report design. (Zenex, n.d.)

1.5 Aim of the Project

The main goal of this thesis was to improve production efficiency by reducing setup time of the milling machine, by modifying Mastercam's default setup sheet, and tool list templates to meet the customer's requirements. Setup time is a source of waste in the milling manufacturing process, here Mastercam setup sheet plays an important role to reduce time in setup time. Making the setup sheet with all necessary information that can be helpful to the machinist. The main objectives and benefits of

modified Mastercam setup sheet are clarity and consistency, setup instructions, tooling information, reduce error, and documentation and record keeping.

A tool list template is a document section in a setup sheet that provides tool related information. The modified tool list in a Mastercam setup sheet refers to customized version of the tool list that is typically included in the setup sheet. The modified tool list provides important information about the tools used in machining process, including tool numbers, description, dimensions, and other relevant details. The aim of this project was also to find out the improvement areas in the Mastercam setup sheet.

2 SETUP SHEET RELATED THEORIES

The Mastercam setup sheet is a critical document used in computer aided manufacturing to ensure efficient and accurate machining operations. Several related theories and principles are applied on development of Mastercam setup sheet template. CNC Machining process, overview of milling manufacturing, SMED methodology and its application in milling manufacturing, Lean methodology and its application in manufacturing, integration of Mastercam setup sheet with SMED and Lean techniques, Mastercam setup sheet and its role in manufacturing efficiency.

2.1 CNC Machining

CNC machining is a manufacturing process that uses computer numerical control machines to create complex part precisely with accuracy. CNC machine control and manipulate the movements of machine tool by computer programs for highly accurate and consistent production of part such as lathes, mills, routers etc. CNC machined part first designed using computer aided manufacturing (CAD) software. The design includes the size depth and any other specification about the desired shaped product. Then cutting tool selected through CAD software according to the materials, shape, and size of the desired product. Thereafter, CAD file put on the CNC machine and CNC machine must be set up for the job. Workpiece clamped on the CNC machine. The tool path is programmed in the CNC machine using CAD software. CNC machine tool works according to the CAD file.(CNC MACHINES, n.d.)

2.2 Overview of Milling manufacturing

Milling is a manufacturing process which involves the removal of materials from the work pieces using a rotating cutting material. This process is commonly used to create various kind of complex parts with precision and accurately for various kind of product making. The milling process is mostly used in wide range of industries including automotive, aerospace, medical. In milling machine cutting tool is mounted on a spindle which rotates at high speed and workpieces are securely clamped on the table or fixture. (SANDVIK n.d.)Spindle tool is a moving part and workpiece is a stationary part in a milling machine. There are various kind of cutting tools depending on the desired outcome. Such as End mill, Face mill, Ball nose cutter, Slot drill, Chamfer mill, T-slot cutter, reaming, Thread mill, Fly cutter, Shell mill, Woodruff cutter. Each cutting tool has specific shape and function to cut a specific kind of materials or shape. End mills are used for cutting flat surfaces or making pocket slot cuts, ball nose cutter is used for contouring or creating rounded shapes. Face mills are used for large surfaces, for cutting slots or channels in a workpiece slot drill are used. Slot milling is to cut a grooving inside the raw material. Reaming process is used after drilling to reamed to achieve a precise diameter. Reamed holes are often used to accurately position items with locating pins. (TESSA AXSOM, 2023.)

The working principle of the milling machine is that highly rotating tools will remove materials from the workpiece and give the work piece the desired shape. Milling machine can be categorized depending on the size and automation though in most of the milling machines the working principle is the same. In Manual milling machine workpiece and cutting tool movement is controlled by the operator. On the other hand, in automated CNC (computer numerical control) milling machine can be programmed to automatically control the entire process. Steps of the CNC milling process are shown below, in Figure 1.

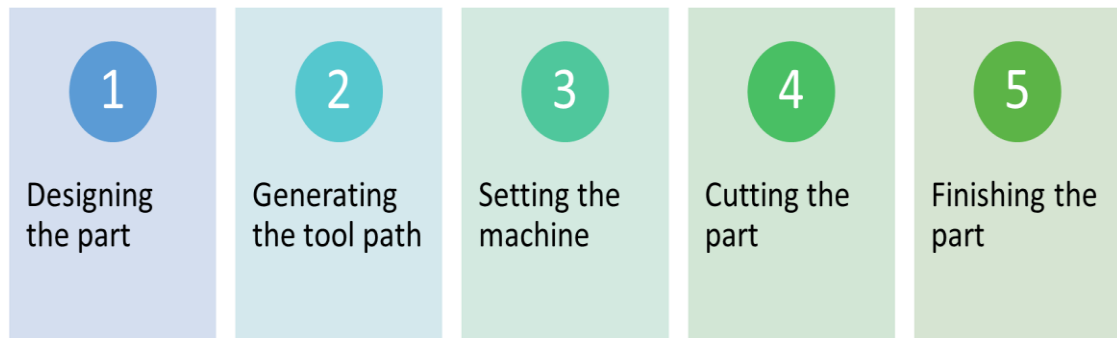


Figure 1 CNC Machine Working Procedure. (ARDEL ENGINEERING, n.d.)

Designing the part: designing the part for CNC machining involves creating a 3D model of a part using computer aided design software and optimizing the design for efficient and accurate manufacturing using CNC machines.

Generating the tool path: Generating tool path is critical in the CNC machining process. It involves determining the precise path that the cutting tool will follow to machine the part. Toolpath generation is typically done using computer aided manufacturing software, that takes into account the part geometry, cutting tools, manufacturing parameters and other factors to create the instructions for the CNC machine.

Setting the machine: setting up a CNC machine involves preparing the machine for operation, ensuring it is properly configured and ready to execute the programmed toolpaths.

Cutting the part using milling machine: Cutting a part using a CNC milling machine involves executing the programmed toolpaths to remove material from workpiece and create the desired shape and features.

Finishing The Part: Finishing the part on a CNC milling machine involves performing the final machining operations to achieve the desired surface finish, accuracy, and dimensional precision.

(Xometry, 2022.)

2.3 SMED methodology and its application in milling manufacturing

SMED is a methodology for reducing the setup time required to switch from one product to another in a manufacturing process. It was developed by Shingo, a Japanese industrial engineer. In milling manufacturing process, SMED methodology can be used to reduce the time it takes to switch between different products or operation on a milling machine because SMED focus to reduce changeover time. (Almomani et al. 2013.)

The first is to identify all the task involve in the set-up process including the internal and external process. This analysis will help to identify effectiveness or waste in the current process. Internal tasks are only performed when the machine is not working, such as changing tool, adjusting the tool and holder, placing the workpieces on table. External activities are done while machine is running such as selecting the tool and workpieces. Doing the external job during internal job that will reduce setup time. Analysing the setup process, eliminating unnecessary steps or using more efficient tools equipment.(Almomani et al. 2013.)

2.4 Lean methodology and its application in manufacturing

Lean methodology is a management philosophy that aims to minimize waste and maximize production quality to satisfied customer. The aim of lean methodology is optimizing the process of creating the value of customers while minimizing waste. This methodology was developed by Toyota in the 1940s and has since adopted by many other manufacturing company. (Kelendar, 2020.) Key principles of lean methodology are.

- Value: Identify and understand the specific value that a product or service provide to the customer. Focus on delivering what the customer truly needs and is willing to pay for, while eliminating activities that do not contribute to what value.
- Value stream: Map out the entire value stream, which includes all the steps and processes required to deliver the product or service. Analyse the value stream to identify areas of waste, bottlenecks, and inefficiencies that can be eliminated or improved.
- Flow: Ensure a smooth and continuous flow of work by removing obstacles and minimizing interruptions or delays. Optimize the sequence of processes to enable a steady and seamless progression of value creation from start to finish.
- Pull: Implement s pull based system where work is initiated based on actual customer demand. Instead of producing or delivering in anticipation of future demand, respond to customer needs by producing or delivering only when requested. This helps to avoid overproduction, excess inventory, and waste.

- Continuous Improvement: Embrace a culture of continuous improvement at all levels of the organization. Encourage employees to constantly seek out ways to eliminate waste, improve processes, and enhance overall performance. Adopt problem solving methodologies such as Kaizen, to systematically identify and implement improvements. (Ribeiro et al. 2019.)

Lean methodology is a powerful tool for improving manufacturing processes and increase efficiency and productivity. By focusing on continuous improvement and eliminating waste, manufacturer can reduce costs, improve quality, and increase customer satisfaction. (Ribeiro et al. 2019.)

2.5 Integration of Mastercam setup sheet with SMED and Lean techniques

Mastercam setup sheet design to focus on the principle SMED and lean techniques because integration Mastercam setup sheet with SMED and lean techniques can increase efficiency and reduce cost in milling manufacturing. In milling manufacturing changeover involve setting up machine for a new product run, this setting up take a significant amount of time. Some ways are mentioned below to integrate SMED with lean techniques for increasing efficiency of milling manufacturing. SMED is a Lean methodology's tool. Some Lean methodology tools are given below.

Value stream mapping (VSM): value stream map helps to identify the nonvalue added step that occur during the milling manufacturing process. This also can help to determine which step can be eliminated or combined with other step, and which can be streamlined to improve efficiency.

Standard work: standard work is a critical tool for lean organization to reduce waste and improve efficiency. The element of the standard work is sequences of works, time required, standard in work process, standard work combination chart. The traditional Mastercam setup sheet helps to fulfil standard work element criteria, so this tool is already applied in Mastercam setup sheet. Those two steps fulfil first two elements criteria.

In each topic Mastercam setup sheet gives visual illustration and Mastercam setup sheet represent itself as document for the milling process.

5s methodology's element are sort, set in order, shine, standardize, sustain. 5S system help to organize the workpieces and reduce the amount of require time. (Smart, 2013.) Mastercam setup sheet helps to implement this step smoothly. During this step Mastercam set up sheet gives details information about production sequence. Depending on the production sequence workpieces also possible to organize. This method will reduce waste of raw material because operator can estimate or make a draft plan how he will cut the workpieces.

2.6 Mastercam setup sheet and its role in manufacturing efficiency

Mastercam setup sheet can increase the production efficiency of milling machine that was partially discussed in previous section. Mastercam setup sheet helps in reducing errors and defects by providing all the necessary information within a short space. Therefore, this reduces the possibility

to make mistake, reduce to make scrap part, or even it reduces machine damage. Due to visual picture of the work pieces, finished product, tool and holder it was not possible to make a faulty product following the setup sheet. It also helps to find out the suitable workpieces for the next production during machine is working for another product. In setup sheet gives a dimension of the workpieces that helps operator to find out the suitable workpieces without wasting raw materials. Mastercam setup give a well-illustrated machine setup details that helps to reduce the machine setup time. By providing information on the tool paths and machining parameters, the setup sheet helps to reduce scrap. There is a comment section in a setup that helps to communicate between the programmer, operator, and quality control personnel.

Overall, a well-designed setup sheet helps to improve manufacturing efficiency by reducing setup time, improving consistency, minimizing scrap, reducing the chances of error, enabling faster setup time for future production and improve communication between teams. (Shukla et al. 2023.)

2.7 Overview of Mastercam setup sheet

Mastercam setup sheet is an automatically generated file which include details information to setup and run a specific CNC machining operation using Mastercam software. The detailed document includes critical document such as tooling details, machining parameters, workpiece dimensions and other all necessary setup details depending on the CNC machine. Setup sheet is created to help the operator to do a specific operation successfully.

There are four step to generate a Mastercam setup sheet. Step of the Mastercam setup sheet shown below, in figure 2.

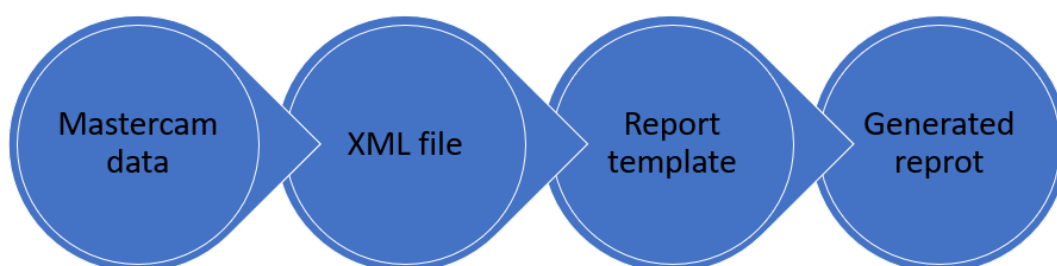


Figure 2. Step of Mastercam setup sheet. (Mastercam, n.d.)

Setup sheet report generated depending on those four steps. Setup sheet modification depends on XML file and report template. Setup sheet report created depending on the report temple and available data on Mastercam.(Mastercam Help Center, n.d.)

3 DEVELOPMENT OF MODIFIED MASTERCAM SETUP SHEET

The development of modified Mastercam setup sheet involves creating a comprehensive document that outline the essential information and instruction for setting up and operating a CNC machine using the Mastercam software. A setup sheet serves as a valuable resource for machine operators, programmers, and other person involves in the machining process. Traditionally, a standard Mastercam setup includes details such as part information, tooling specifications, cutting parameters and machine setup instructions. However, a modified Mastercam setup goes beyond these basics to provide additional relevant information and enhancements that improve efficiency, accuracy, and productivity in the machining process.

3.1 Development of Mastercam setup sheet with active report designer

Mastercam setup sheet modification was done by Active report designer. Active report designer is a software tool used for designing and generating setup sheet in conjunction with Mastercam. Active report designer allows you to create customized setup sheet that include relevant information about the machining process, tooling, workpiece setup and other details about the machining process. First active report designer needs to be connected with a XML file. Then Active report designer allows you to connect report elements to data sources. Active report designer provides design tools and elements such as text boxes, table charts, images, and shape that you can drag and drop onto the design canvas.(FASTech, Inc, 2015.)

To add any kind of data Mastercam provided specific XML tags need to add on the Active report designer software. Those XML tags contain a specific information for Mastercam setup sheet.

Those XML code changes the main XML file due to change in the Mastercam design software. This procedure makes the modification easier, and this Active report designer software doesn't require any coding experience to modify a setup sheet. Active report designer work as a third party between XML file and Mastercam. Mastercam setup sheet generated depending on the XML file and Mastercam given instruction. User only need to know with the active report software. Active report information is possible to organize depending on the need. There are various kind of CNC machine and depending on the CNC machine needed information from the setup sheet varies. It is possible to arrange the order of information in the setup sheet according to the order of the information required by the CNC machine. If the setup sheet organized in such way, it helps the operator to find out needed information quickly. That will reduce the setup time.

Active report design can create the report in various formats such as PDF, excel, HTML or as printout layout. Active report designer combines the report layout with the data form your connected data source to create the final report. Active report designer provides a flexible and powerful environment for designing report, making it easier to present the data in a meaningful and visually appealing manner. Active report designer able to make simple and complex both reports to meet the reporting requirements. (CNC Cookbook n.d.)

3.2 Features of the modified setup sheet

The setup sheet modified depending on the provided features of the Active report designer software and needed information to operate CNC milling machine. Mastercam generated setup sheet modified by Active Report designer software and this software was developed by GrapeCity, a software development company. It offers a comprehensive set of design tools and features that enable developers to design visually appealing and interactive report. The active report designer support various data sources, including XML, JSON, and custom data sources.(GrapeCity, n.d.)

The active report designer software includes a wide range of data visualization control, such as charts, gauges, maps, and sparklines. Those controls can be easily configured and customized to present data in a visually compelling manner, making it easier for users to understand and analyze the information presented in the report. The software provides a report preview functionality, allowing developer to view and interact with the report during the design process. It supports various export options, including PDF, Excel, Word, HTML and more, enabling reports to be easily shared and distributed in different format.(GrapeCity, n.d.)

Active report designer support scripting language like C# and Visual Basic, allowing developers to extend the functionality of their reports. C# and Visual Basic can be used to develop custom functionalities or applications that interact with active Report Designer, and XML file. XML is a file format used for storing and exchanging data. Mastercam export data including tooling information, machining parameters and part details in an XML format. This XML export feature allows to extract relevant information according to modified Active report designer.(Papaleo, 2014.)

3.3 Implementation challenges and solutions

Mastercam setup sheet report requires a good experience about the Mastercam active report designer software. There are some books available on website about Mastercam setup sheet, YouTube video, articles, and Mastercam website is also source of information that helps to manage setup sheet design software. It is hard to filter and sort data in order to generate meaningful data. For a specific machine designer need to select what will include and what will not include on the setup sheet. Otherwise, the setup sheet will look messy and setup sheet will too long. Due to this to find out the necessary information operator need to consume time.

4 METHOD TO DEVELOP THE SETUP SHEET

There are a few requirements that are needed to develop a setup sheet. These requirements include the following.

- Understanding basic of the CNC machining process and the specific requirements for setting up the machine.
- Determining the structure of the setup sheet based such as general information, tooling information, workpiece setup, machine setup, cutting parameters, visual aids etc.
- Considering the logical flow of task in machining process.

This section explains a systematic method that involves gathering the necessary information, organizing it effectiveness, easy understanding of the layout design.

4.1 Improvement areas for setup sheet

First it has to be confirmed that Mastercam setup sheet is providing all necessary information required for a CNC machine. Such as part name, revision, machine type, tooling details, work holding device, details about workpieces, workpiece clamping position on the machine etc. Then, the information must be placed in a short format with proper visuality. Short pages information saves time and easy to find information. Using pictures or diagrams of the parts, tooling can provide a clear visual information for the machinist. Graphics can be used to illustrate the machining process, providing a clear understanding of how the part will be machined. Example clearly provide information the holder's name, tool name, tool number, tool offsets, holder length, tool length etc. organize the setup sheet information depending on the machine needed information. There is a comment section in Mastercam setup sheet where different sectioned people can communicate and give feedback or some kind of instruction.

Those are the few potential areas for improvement in the Mastercam setup sheet. Continuous user feedback, regular updates, and incorporating emerging technologies can further enhance the tools capabilities and address the evolving needs of CNC machining process. (Lauzier, 2022.)

4.2 Research design

The research was begun with learning about the Active report designer software and understand the specific CNC machine setup information requirements. This includes the machine type, workpieces dimensions, workpiece holding information, machining operation, toll name, tool number, tool code, tool input length, materials, and other relevant details. Then organize that information on the setup sheet depending on a specific CNC machine needed information requirement.(ZENEX n.d.)

After that, present the information is a structured and sequential manner that ensure that is easy to follow. By making the text size bold, changing the text colour, adding visual illustration helps the user to the information quickly. To learn the Active report design software the Mastercam web site, some online web pages, pdf, and you tube video those plays an important role. Mastercam helps to

get the overview idea about the Active report software.(Mastercam Help Center, n.d.) Zenex provided book also gives idea about Active report designer software. It illustrates use of active report designer software.

4.3 Data collection for modified Mastercam setup sheet

The setup sheet was modified according to the company needed requirement. Company gets those requirements from their customer feedback. Their provided information is essential to operate CNC milling machine operation. Their required information about tool list shown below, in Figure 3.

TYÖKALULUETTELO										3.3.2023	11.59
Mastercam Mill.NC											
Nro	Pit.	Säde	Työkalun nimi	Valmistaja	Halk	Säde	Pituus	Kokoonpano	Pidin	Mitattu	
	Komp.	Komp.					pitimest	n pituus		Valmistaja	pituus
1	1	1	F5141.B16.040.Z04.12	Walter Tools	40.0	0.8	40	78.036	A155.BT40.035.16	Walter Tools	
2	2	2	MD128-16.0A6L050J-WJ30RD	Walter Tools	16.0	0.5	67	139.5	AK182.BT40.072.20	Walter Tools	
3	3	3	MD340-05.0A3PC-WK40TP	Walter Tools	5.0	0.0	40	110	AK182.BT40.058.12	Walter Tools	
4	4	4	D4120-03-30.00F32-P45	Walter Tools	30.0	0.0	122	222	AK170.BT40.100.32	Walter Tools	
5	5	5	DA110-08-05.000U0-WZ90AJ	Walter Tools	5.0	0.0	52	122	AK300.BT40.070.	Walter Tools	
6	6	6	DC170-03-06.900A1-WJ30EJ	Walter Tools	6.9	0.0	45	103	AK182.BT40.058.12	Walter Tools	
7	7	7	H1E58318-E10-10	Walter Tools	10.0	0.0	60	132.5	AK182.BT40.072.20	Walter Tools	
8	8	8	TC120-M8-C1-WW60AG	Walter Tools	8.0	0.0	60	130	AK300.BT40.070.	Walter Tools	
9	9	9	TC120-M6-C0-WW60AG	Walter Tools	6.0	0.0	50	120	AK300.BT40.070.	Walter Tools	

Figure 3 Information about tool list and holder. (Vepsalainen, 2023.)

The above-mentioned information is related on tool and holder. The tool list gives information about the tool according to the operator needed information. The above-mentioned information was provided by Camcut Oy specialist. (Vepsalainen, 2023.)

There also some other information is added in the setup sheet to make the machine setup process easier. Above mentioned figure shows information about the holder and tool. To continue CNC milling machine setup process some other information also needed like part information, machining operation, work offset and safety note or comment section. In milling process most essential information that required from Mastercam setup sheet include job name, number, material type, tool type, raw material size and finished product, machining operation details, tool and holder details, holder, and tool position details. Those mentioned information are helps to ensure that the machining process is efficient, accurate consistent. Because that information is essential to setup a CNC milling machine. (Lipponen, 2023).

4.4 Documentation and visualization techniques

A setup sheet is Collected data source for the specific CNC machine for operator. Setup sheet contains information about CNC machining operation that helps the operator to operate CNC machine smoothly. Data mentioned in chapter 4.3 is collected from the observation of CNC machining process, feedback from industry professional.

The modified setup sheet organizes the information in a logical and user-friendly manner for Milling machine. The modified setup sheet visualizes the document according to the CNC machine required information sequence. Some information is highlighted by changing the letter from size making the

word bold to make the information visibility clearer. Utilizing table charts to present information such as tool lists cutting parameters, and machining sequences provide more clarity in the setup sheet. The Mastercam setup sheet allows to add image. Adding a company logo on the setup sheet can help to personalize the document and make it more recognizable to the intended audience. Adding a company logo can be one part of this process. Including a logo reinforce company branding and present a more professional image to clients or partners. The modified Mastercam setup sheet front page mentioned below.

The modified Mastercam front page mention that the setup sheet contains less page with all necessary information. Modified Mastercam setup sheet focus on visuality. Modified setup sheet improve visuality with picture, word front side, information sequence. In front page the company logo is possible to added that make gives the setup sheet recognition as mentioned company materials. In this page used machine picture and the workpieces shape also visible. The workpieces dimensions also mentioned on the front page.(FASTech, Inc. 2015 .)

Operation information is also important part in milling process. The modified Mastercam setup sheet should give overview of the operation in a CNC machining process. In this section clear overview about the operation information is very important. The one of the important parts is of setup sheet is tool list. Tool list plays crucial role for efficient and effective CNC milling operation. Tool information on the modified setup sheet should include all necessary information that needed on the machining process. Right tool information is the prerequisite of machining process.

Work offsets of the modified setup sheet gives a basic information about the operation. It gives information about the sequence of operation.

5 RESULTS

Mastercam setup sheet has a crucial effect on CNC machining process. By incorporating SMED and lean principles into a Mastercam setup sheet it is possible to achieve several positive outcomes including reduction of changeover time, increasing efficiency, improved productivity and minimized waste. Mastercam setup sheet and lean methodologies all are related to the improvement of manufacturing process and the reduction of waste. There is not direct link between Mastercam setup sheet and SMED/Lean, they can be used together to achieve process efficiency and productivity enhancements.

The focus of SMED is to reduce changeover time in manufacturing process and Mastercam setup sheet contribute to SMED to reduces changeover time by providing detailed instructions and standardized procedures for setting up the CNC machine. In chapter 5.1 the modified setup sheet and SMED relation are illustrated.

SMED and Lean are closely related methodologies that share common goals of waste reduction, efficiency improvement, and continues improvement.

The modified Mastercam setup sheet utilized Lean manufacturing technology as a tool to improve the Milling operation process. According to the Lean methodology's principle are modified Mastercam setup up is analyse in section 5.2. the discussion of this section proved that the how lean methodology is implemented in Mastercam setup sheet.

5.1 Analysis of modified setup sheet considering SMED

The modified Mastercam setup sheet, implemented with single minute exchange of die principles, can significantly impact the setup time and overall efficiency of CNC machining operations. Analysis of the traditional setup sheet and modified setup sheet can prove that modified setup sheet saves time. In all production methodology making setup time short is essential part. Single Minute Exchange of Die that reduce the time by converting external work to internal work. (Almomani et al. 2013) In milling machine operation some works are possible to do during the milling machine is running and some tasks are not possible to do during the milling machine running. Internal work is not possible to do when the equipment is running, and external work is possible to do when equipment is running. Modified Mastercam setup sheet information helps the operator to do the External work when internal work is running. According to the SMED external work are possible to do during internal work. External work in milling include:

- Preparing tooling and cutting tools required for the upcoming setup.
- Gathering necessary work holding devices or fixtures.
- Prepare workpieces for the next job.
- Collecting or preparing auxiliary equipment or materials needed for the setup.

The total time of CNC milling operation time possible to decreased by doing external work parallely with internal work with the help of modified Mastercam setup sheet. Modified Setup sheet provide all necessary information to do the external work during internal work time. Without a informative setup sheet it is not possible to select the tool, workpieces and internal works. So, modified setup sheet reduce setup time in milling operation and satisfy SMED methodology.

The traditional setup sheet gives some additional information in the setup sheet and some information is missing for a specific machining process. Due to the additional information the traditional setup sheet takes extra pages than modified setup sheet. So, using the modified Mastercam setup sheet is convenient and time saving to the operator. So due to the page quantity the modified Mastercam setup sheet takes less time to find necessary information for milling process.

Due to workpieces information in the modified setup sheet operator can find out suitable workpieces for the next operation while machine is running of the current operation that saves time for the next operation.

The modified tool list includes all essential information that required for the CNC milling machine. That information is organised according to the operation needed information sequence that is why operator does not need to find information to setup a tool. Operation also prepares the tool for the next CNC milling operation during the machine is running. That also reduce tool setup time and support SMED methodology.

The work offsets of the modified Mastercam setup sheet gives operation overview withing short space that helps to the operator to know overview of the operation. That also time saving that operator got information about the operation of the milling process. From this part operator knew the sequence of the operation.

WORK OFFSETS

OFFSET INFO

NUMBER:	0	PLANE:	Päättä	ORIGIN:	0.0, 0.0, 0.0
USED BY OPERATION:	# 2	2 - 2D High Speed (2D Dynamic Mill)			
USED BY OPERATION:	# 3	3 - 2D High Speed (2D Dynamic Rest)			
USED BY OPERATION:	# 4	4 - 2D High Speed (2D Dynamic Mill)			
USED BY OPERATION:	# 5	5 - 2D High Speed (2D Dynamic Mill)			
USED BY OPERATION:	# 6	6 - Contour (2D)			
USED BY OPERATION:	# 7	7 - Contour (2D)			
USED BY OPERATION:	# 8	8 - Contour (Ramp)			
USED BY OPERATION:	# 9	9 - Contour (Ramp)			
USED BY OPERATION:	# 10	10 - Drill/Counterbore			
USED BY OPERATION:	# 11	11 - Drill/Counterbore			
USED BY OPERATION:	# 12	12 - Drill/Counterbore			
USED BY OPERATION:	# 13	13 - Chamfer Drill			
USED BY OPERATION:	# 14	14 - Model Chamfer			
USED BY OPERATION:	# 15	15 - Tap			
USED BY OPERATION:	# 16	16 - Tap			

Figure 4 Modified setup sheet work offset. (Sarker, 2023)

Overall, modified Mastercam setup sheet helps to reduce change overtime on milling operation by reducing each step setup time. That also increasing the machine efficiency and productivity.

5.2 Analysis of sheet Considering lean methodology

Lean methodology is a set of principle that aim to optimize processes, minimize waste, and maximize value in a business or manufacturing environment. The primary goal of lean is adding value to customers and eliminate waste in all its forms. The core principle of lean is waste reduction, continuous improvement, value stream mapping, and standardized work. (Leksic, Stefanic and Veza, 2020.) There are eight categories of waste. Many companies become more competitive following the waste reduction technique, but some companies are facing failure. The waste is considered as "Muda". The waste in Lean is overproduction, waiting time, transportation, motion, unnecessary inventory, overprocessing, defects, and underutilized talent. Overproduction refers to producing more products, parts, or services. Waiting time refers to the period when a product is idle or not actively being processed. Waiting time is considered a form of waste. In lean methodology transportation waste refers to the unnecessary movements or transportation of materials, product, or information that doesn't added value to the customer. In lean manufacturing motion waste refers to any unnecessary or excessive movements of people, equipment, or tools that doesn't added any value to customer and product. Unnecessary inventory waste refers to holding more inventory than production or customer demand. Producing more product than customer demand is called overprocessing waste in lean. In lean methodology defect waste refers to any product or services that does not require customer specifications or expectations. (Leksic, Stefanic and Veza, 2020.)

The modified Mastercam setup sheet involves reducing the waste. The setup sheet reduces waste of workpieces. The modified setup sheet gives the exact size and shape of the workpieces that reduces the waste of raw materials. The workpieces information helps the operator to select the workpieces when machine is working, and this process will save machine setup time for the next job.

The workpieces information help to save time to the operator that reduce the waste of time. Workpieces information helps to organize the use of raw materials that reduce the time and save raw materials. workpieces information ensures the proper dimensioned workpieces.

Overall, workpieces information reduce waste of time and raw materials and waste reduction is primary goal of Lean principle.

This modified tool list contributes to the lean principle by improving machine setup efficiency, reducing waste. The setup sheet illustrates the tool with picture and gives a full specification of the tool that reduces the setup time. The specification of the tool list reduces chance of mistake. Clearly specify tool dimensions, part numbers, identification codes, or other specification avoid tooling error that prevent producing defective product. Visual management technique is used on above mentioned tool to helps the operator quickly identify and locate the required tools, reducing search time and errors. Prevent defective product is also principle of lean methodology. 5S principle of the lean is implemented on the above tool list. The mentioned tool list is sorted and organized logically depending on the necessity of operator need information that is following the 5S rules of lean.

The modified setup sheet tool list modified following lean principle that can make operator works more efficient and effective.

5.3 Comparison with traditional setup sheet

There are lots of difference between traditional and modified setup sheet. Traditional Mastercam setup sheet is not made for a specific CNC milling machine, it is made for capturing the technical details of the machining process, such as tooling specifications, cutting parameters, and machine settings. The traditional setup sheet is not prioritizing the efficient changeover of setups. It lacks detailed information on tooling changeover, and other information that involved in the setup process. Most of the traditional setup sheet did not gives information about Holder manufacturer, tool manufacturer, insert code that kind of information. The traditional setup sheet did not focus on reduce waste or reduce setup time. On the other hand, modified setup sheet are made to increase the production efficiency. In modified setup sheet, visual issues are solved as operator's convenience. Usually, traditional setup sheet comes with lots of information those traditional setup sheet does not focus on a specific machine.

So, there are some information lacks in a traditional setup sheet for a specific machining process. On the other hand, modified setup sheet are made with in few pages that helps the operator to find out the needed information easily. First page of the traditional setup sheet and modified setup sheet is illustrated below in Figure 5 and 6.

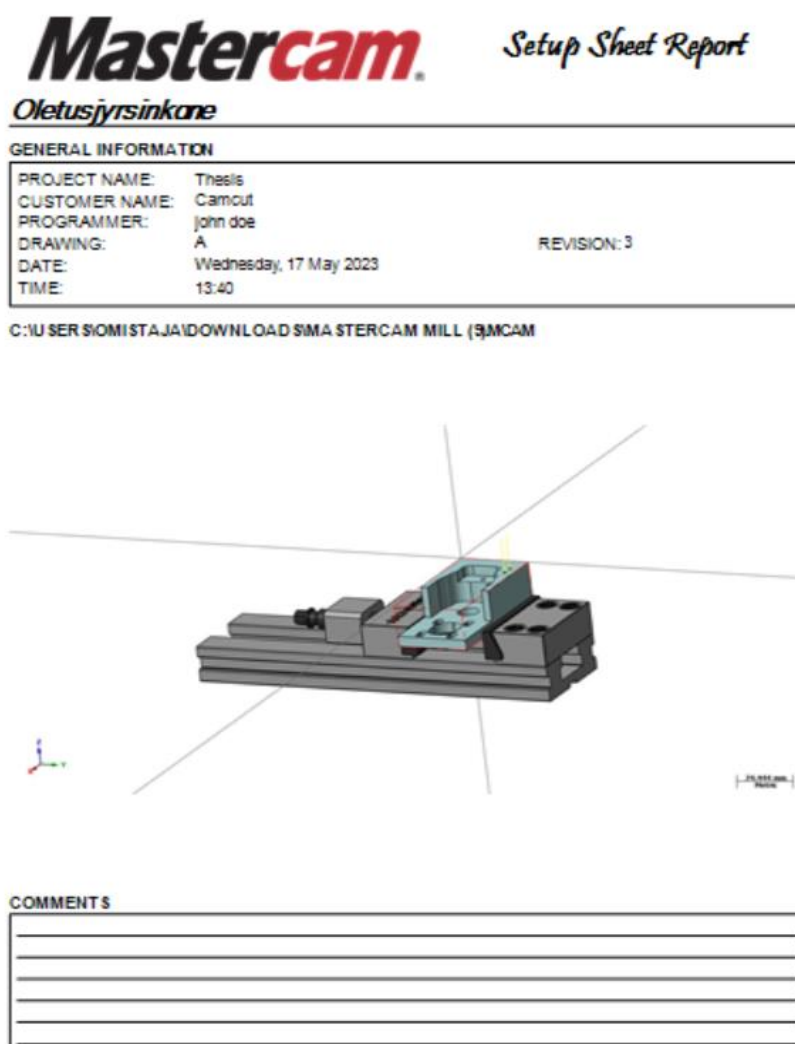


Figure 5 Traditional setup sheet Front Page. (Sarker, 2023)

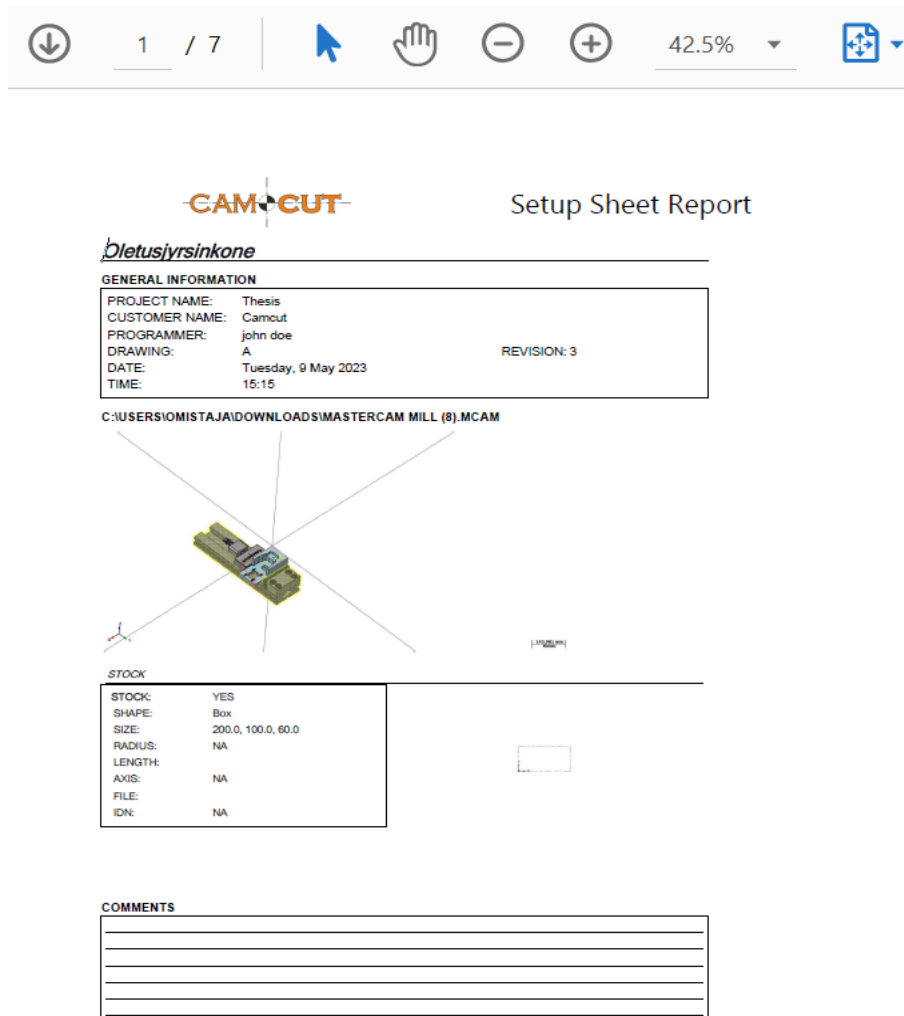


Figure 6 Front page of modified Mastercam setup sheet. (Sarker, 2023)

There are few differences between front page of modified and traditional setup. Modified setup sheet represent a specific company on the other hand traditional setup sheet doesn't represent any company. Traditional setup sheet generally did not include workpieces information on the front page, but the modified setup sheet include that gives information about the workpieces to the operator.

The workpieces information helps to organize the workpieces that reduce waste of the workpieces. Workpieces information are helping to set the workpieces on the machine that reduce time because the operator does not need to collect the workpieces information from another document.

Above mentioned two pictures clearly proves that there is lots of difference between modified setup sheet and traditional setup sheet. Tool list details of traditional and modified set up sheet are illustrated bellow, in figures 7 and 8.

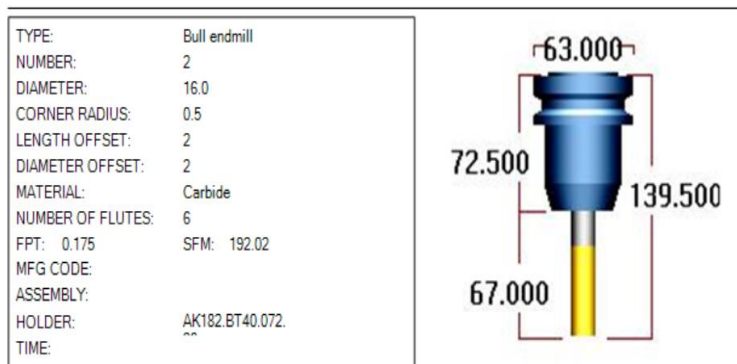


Figure 7 Traditional setup sheet. (Sarker, 2023)

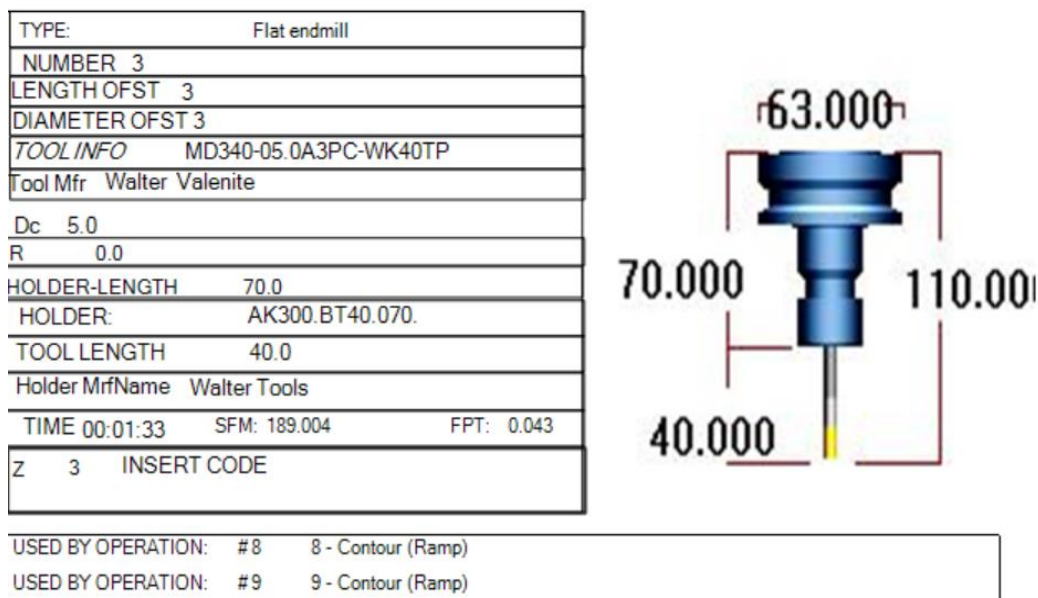


Figure 8 Modified setup sheet tool info. (Sarker, 2023)

There are lots of difference between traditional setup sheet and modified setup sheet. The modified setup sheet tool list includes information about type, number, length offset, diameter offset, tool info, tool holder manufacturer, diameter, corner radius, holder length, holder length, tool length, holder manufacturer, insert code. That information essential information for CNC milling operation and the modified setup sheet focus to include that information. There are various kind of default setup sheet. Those setup sheet does not include all the mentioned tool information. Overall, that information are not organized according to the operator need. Lack of essential information is causes to the machine damage and increase possibility of the fault production. The traditional setup sheet typically follows a standard format provided by the software. It gives comprehensive information in some section for all kind of machine that used Mastercam.

The modified setup sheet helps to reduce error in tool setup and reduce machine damage. Due to error in tool setting the change of fault product increase. So, the modified tool list reduces fault production. The sequence of tool list reduce time in tool settings. Operation list of traditional setup sheet shown below, in Figure 10 and also the operation list of modified setup sheet illustrated Figure 9.

CYCLE TIME: 0 HOURS, 4 MINUTES, 7 SECONDS

OPERATION LIST

OPERATION INFO	2- 2D High Speed (2D Dynamic Mill)
CYCLE TIME:	0 HOURS, 4 MINUTES, 7 SECONDS

Figure 9 Operation list Of Modified Setup sheet. (Sarker, 2023)

OPERATION LIST

OPERATION INFO	2- 2D High Speed (2D Dynamic Mill)
CYCLE TIME:	0 HOURS, 4 MINUTES, 7 SECONDS
PROGRAM NUMBER:	0
SPINDLE SPEED:	2292 RPM
FEEDRATE:	2145.312 mm/min
CLEARANCE PLANE:	50.0
RETRACT PLANE:	10.0
FEED PLANE:	3.0
DEPTH:	0.0
STOCK TO LEAVE:	0.0 0.5
COMP TO TIP:	YES
WORK OFFSET:	0
Cutter compensation	Computer




Figure 10 Operation List traditional setup sheet. (Sarker, 2023)

There are lots of difference between the modified Mastercam setup sheet operation list and the traditional setup sheet operation list. The operation is list modified focusing on the needed information from the operation list for CNC milling process. The modified setup sheet focus on the CNC milling machine. The modified setup sheet operation list gives all necessary information about the operation of milling process. Finding information about operation list form the modified setup sheet is easier than traditional setup sheet. That reduce information collection time and reduce chance to mess up with other information.

6 CONCLUSIONS AND DISCUSSION

The aim of this project was to reduce non value added production time and increase efficiency by making setup sheet with essential information for the milling. SMED and Lean principles into a modified Mastercam setup sheet can bring significant benefits to machining process. SMED and lean methodology help to reduce waste, they improve efficiency, reduce downtime, enhance overall productivity. In the modified set up sheet, which incorporates lean principles, it is focused on eliminating all kind of waste through setup sheet, improving flow, and optimizing the setup process. By reducing the non-value-added activities, such as searching for tools or adjusting machine settings, the overall efficiency of the setup is improved. This shortens changeover times and increases machine uptime.

The modified Mastercam setup sheet, incorporating lean principles and SMED techniques, significantly improved the manufacturing process. The modified setup reduces setup time by including all essential information for milling. The modified setup sheet information is organized depending on the operation needed information sequence that reduce time significantly. Thus, the modified setup sheet can reduce CNC milling setup time. This modified setup sheet provides all necessary information about tool. This tool information working as a error proofing techniques that reduce machine damage and reduce faulty production.

The future development of the Mastercam setup sheet is expected to embrace digitalization, automation, and data driven approaches. Developing mobile application for easy access to setup instructions and reference materials on handheld device.

In conclusion the modified Mastercam setup sheet serves as a valuable tool in enhancing manufacturing operation. Effect of the modified setup sheet is discussed above. The modified setup sheet offers tangible benefits such as standardization, reduce setup time, improved productivity, waste reduction, enhance product quality. By following the methodology in modified setup sheet the company can optimize their setup processes and achieve operational excellence.

The project work contained a few steps. The setup sheet modification was started by reviewing the existing setup sheet. Then based on analysis requirement and depending on available option the new setup sheet was developed. The setup sheet was focused to improve the production efficiency. This process gives an idea about Lean methodology and SMED broadly. This also gives idea about the Active report designer software that will create another setup sheet.

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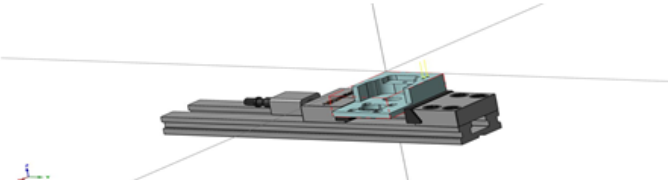

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APPENDIX 1: MASTERCAM SETUP SHEET FOR MILLING

CAMCUT		Setup Sheet Report																		
<i>Oletusjyrsinkone</i>																				
GENERAL INFORMATION																				
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PROJECT NAME:	Thesis																			
CUSTOMER NAME:	Camcut																			
PROGRAMMER:	john doe																			
DRAWING:	A	REVISION:3																		
DATE:	Tuesday, 30 May 2023																			
TIME:	13:50																			
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TOOL LIST

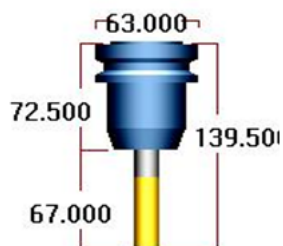
Sorted: NO

TYPE:	Bullendmill
NUMBER	1
LENGTH OFST	1
DIAMETER OFST	1
TOOL INFO	F5141.B16.040.Z04.12
Tool Mfr	Walter Valenite
De	40.0
R	0.8
HOLDER-LENGTH	38.036
HOLDER:	A155.BT40.035.16
TOOL LENGTH	40.0
Holder MfrName	Walter Valenite
TIME	00:04:07 SFM:288.03 FPT: 0.234
Z	4 INSERT CODE LNMU130608R-L55T WKP35G



USED BY OPERATION: #2 2-2D High Speed (2D Dynamic Mill)

TYPE:	Bullendmill
NUMBER	2
LENGTH OFST	2
DIAMETER OFST	2
TOOL INFO	MD128-16.0A6L050J-WJ30RD
Tool Mfr	Walter Valenite
De	16.0
R	0.5
HOLDER-LENGTH	72.5
HOLDER:	AK182.BT40.072.
TOOL LENGTH	67.0
Holder MfrName	Walter Tools
TIME	00:00:59 SFM:192.02 FPT: 0.175
Z	6 INSERT CODE



USED BY OPERATION: #3 3-2D High Speed (2D Dynamic Rest

USED BY OPERATION: #4 4-2D High Speed (2D Dynamic Mill)

USED BY OPERATION: #5 5-2D High Speed (2D Dynamic Mill)

USED BY OPERATION: #6 6-Contour (2D)

USED BY OPERATION: #7 7-Contour (2D)

TOOL LIST

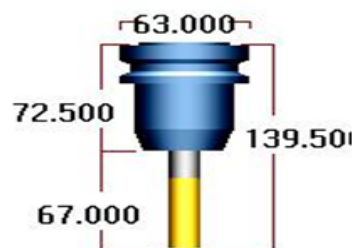
Sorted: NO

TYPE:	Bull endmill
NUMBER	1
LENGTH OFST	1
DIAMETER OFST	1
TOOL INFO	F5141.B16.040.Z04.12
Tool Mfr	Walter Valenite
De	40.0
R	0.8
HOLDER-LENGTH	38.036
HOLDER:	A155.BT40.035.16
TOOL LENGTH	40.0
Holder MfrName	Walter Valenite
TIME	00:04:07 SFM:288.03 FPT: 0.234
Z	4 INSERT CODE LNMU130608R-L55T WKP35G



USED BY OPERATION: #2 2 - 2D High Speed (2D Dynamic M)

TYPE:	Bull endmill
NUMBER	2
LENGTH OFST	2
DIAMETER OFST	2
TOOL INFO	MD128-16.0A6L050J-WJ30RD
Tool Mfr	Walter Valenite
De	16.0
R	0.5
HOLDER-LENGTH	72.5
HOLDER:	AK182.BT40.072
TOOL LENGTH	67.0
Holder MfrName	Walter Tools
TIME	00:00:59 SFM:192.02 FPT: 0.175
Z	6 INSERT CODE



USED BY OPERATION: #3 3 - 2D High Speed (2D Dynamic Rest

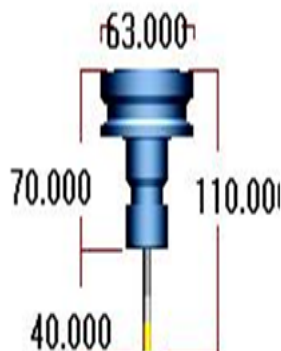
USED BY OPERATION: #4 4 - 2D High Speed (2D Dynamic M)

USED BY OPERATION: #5 5 - 2D High Speed (2D Dynamic M)

USED BY OPERATION: #6 6 - Contour (2D)

USED BY OPERATION: #7 7 - Contour (2D)

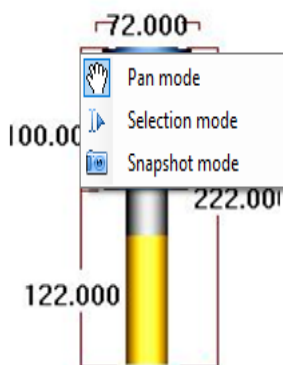
TYPE:	Flat endmill
NUMBER	3
LENGTH OFST	3
DIAMETER OFST	3
TOOL INFO	MD340-05.0A3PC-WK40TP
Tool Mfr	Walter Valenite
D _o	5.0
R	0.0
HOLDER-LENGTH	70.0
HOLDER:	AK300.BT40.070.
TOOL LENGTH	40.0
Holder MfrName	Walter Tools
TIME	00:01:33 SFM: 189.004 FPT: 0.043
Z	3 INSERT CODE



USED BY OPERATION: #8 8-Contour (Ramp)

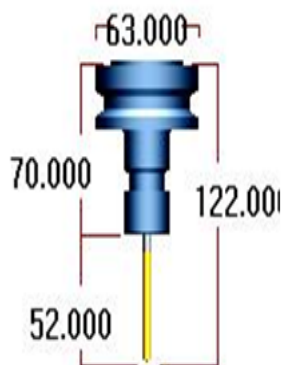
USED BY OPERATION: #9 9-Contour (Ramp)

TYPE:	Drill
NUMBER	4
LENGTH OFST	4
DIAMETER OFST	4
TOOL INFO	D4120-03-30.00F32-P45
Tool Mfr	Walter Valenite
D _o	30.0
R	0.0
HOLDER-LENGTH	100.0
HOLDER:	AK170.BT40.100.
TOOL LENGTH	122.0
Holder MfrName	Walter Valenite
TIME	00:00:03 SFM: 426.013 FPT: 0.129
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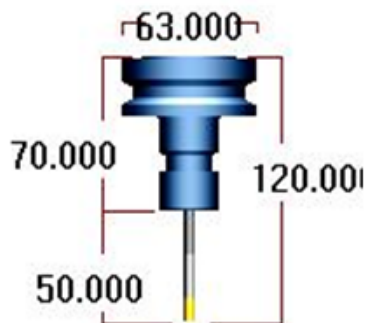
USED BY OPERATION: #10 10-Drill/Counterbore

TYPE:	Drill
NUMBER	5
LENGTH OFST	5
DIAMETER OFST	5
TOOL INFO	DA110-08-05.000U0-WZ90AJ
Tool Mfr	Walter Valenite
D _o	5.0
R	0.0
HOLDER-LENGTH	70.0
HOLDER:	AK300.BT40.070.
TOOL LENGTH	52.0
Holder MfrName	Walter Valenite
TIME	00:00:15 SFM: 19.494 FPT: 0.106
Z	1 INSERT CODE



USED BY OPERATION: #11 11-Drill/Counterbore

TYPE:	Right-hand tap
NUMBER	9
LENGTH OFST	9
DIAMETER OFST	9
TOOL INFO	TC120-M6-C0-VW60AG
Tool Mfr	Walter Valenite
Dc	6.0
R	0.0
HOLDER-LENGTH	70.0
HOLDER:	AK300.BT40.070.
TOOL LENGTH	50.0
Holder MfrName	Walter Valenite
TIME	00:00:01 SFM: 35.891 FPT: 1.0
Z	1 INSERT CODE



USED BY OPERATION: #16 16 - Tap

WORK OFFSETS

OFFSET INFO

NUMBER: 0	PLANE: Pääta	ORIGIN: 0.0, 0.0, 0.0
USED BY OPERATION: #2	2 - 2D High Speed (2D Dynamic M)	
USED BY OPERATION: #3	3 - 2D High Speed (2D Dynamic Rest	
USED BY OPERATION: #4	4 - 2D High Speed (2D Dynamic M)	
USED BY OPERATION: #5	5 - 2D High Speed (2D Dynamic M)	
USED BY OPERATION: #6	6 - Contour (2D)	
USED BY OPERATION: #7	7 - Contour (2D)	
USED BY OPERATION: #8	8 - Contour (Ramp)	
USED BY OPERATION: #9	9 - Contour (Ramp)	
USED BY OPERATION: #10	10 - Drill/Counterbore	
USED BY OPERATION: #11	11 - Drill/Counterbore	
USED BY OPERATION: #12	12 - Drill/Counterbore	
USED BY OPERATION: #13	13 - Chamfer Drill	
USED BY OPERATION: #14	14 - Model Chamfer	
USED BY OPERATION: #15	15 - Tap	
USED BY OPERATION: #16	16 - Tap	

APPENDIX 2: Tool list for milling



Oletusjyrsinkone

Tool Report

MASTERCAM MILL.NCI

TOOL LIST

Sorted: NO

NUMBER	LENGTH OFST	DIAMETER OFST	Holder Mfr.	Dc	R	TOOL LENGTH	HOLDER	Tool Mfr.	TOOL INFO
1	1	1	Walter Valenite	40.0	0.8	40.0	A155.BT40.035.16	Walter Valenite	F5141.B16.040.Z04.2
2	2	2	Walter Tools	16.0	0.5	67.0	AK182.BT40.072.20	Walter Valenite	MD128-16.0A6L050J-WJ30FD
3	3	3	Walter Tools	5.0	0.0	40.0	AK300.BT40.070.ER16	Walter Valenite	MD340-05.0A3PC-WK40TP
4	4	4	Walter Valenite	30.0	0.0	122.0	AK170.BT40.100.32	Walter Valenite	DA120-03-30.00F32-P45
5	5	5	Walter Valenite	5.0	0.0	52.0	AK300.BT40.070.ER16	Walter Valenite	DA110-08-05.000U0-WZ90AJ
6	6	6	Walter Valenite	6.9	0.0	45.0	AK182.BT40.058.12	Walter Valenite	DC170-03-06.900A1-WJ30EJ
7	7	7	Walter Valenite	10.0	0.0	60.0	AK182.BT40.072.20	Walter Valenite	H1E58318-E10-10
8	8	8	Walter Valenite	8.0	0.0	60.0	AK300.BT40.070.ER16	Walter Valenite	TC120-M8-CF-WW60AG
9	9	9	Walter Valenite	6.0	0.0	50.0	AK300.BT40.070.ER16	Walter Valenite	TC120-M6-C0-WW60AG