Northern Alberta Institute of Technology
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Karma: Rapid Changeover of a Production Cell Report

As a submission to

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1.0 INTRODUCTION

Pseudo Techs have been tasked with the responsibility of optimizing the time required to changeover a production cell for Karma Machining and Manufacturing Ltd. The current changeover time is considered too long to maintain productivity and stay competitive in the market. Karma would like to be the sole distributor of a specific product, which will be referred to as S19, for a customer that they value. The Team Sponsor mentioned that every customer looks for 3 requirements from a distributor: they want it cheap; they want it fast; and they want it perfect. Therefore, Pseudo Techs biggest concern on this project was analyzing and suggesting improvements that will allow the costumer to receive the product quicker, cheaper and at a higher quality. The most efficient way to achieve this is by reducing the changeover time within the production cell. The Team Sponsor also mentioned that 95% of activities in a machine shop is non-value added, which means that 95% of activities that the customer is not willing to pay for. Therefore, the extra cost associated with the non-value-added activities must come from the companies profits and not the customer. A changeover is a non value-added task, so it is crucial to minimize times related to changeovers in order to decrease the amount of non-value-added in order to reduce costs.

1.1 Background and Problem Statement

A changeover is defined as the time required to change from the last good part of the previous production run to the first good part of the next production run. Reducing the time taken to complete a changeover is crucial in remaining competitive in the market because it reduces selling price and allows the product to move to the market quicker, which means the shop can accommodate more customer demand with more flexibility.

Karma wants to be the sole producer of the S19 product family for the customer that it is purchasing the S19 parts. In order to stay competitive and remain a valued distributor for this company, Karma needs to reduce the time required to complete a changeover in this production cell so they are able to complete as many changeovers as possible and in turn produce more parts in a shorter period of time.

As competition increases, companies are less flexible when it comes to choosing a selling price. Typically, this means reducing profits in order to compete with other manufacturers. However, the profits can be recovered from the non-value-added tasks, because these are usually payed for by the company and not the costumer. Karma has made the decision that setup times need to be reduced in order to maximize the number of changeovers possible per day; this allows the company to be more flexible towards customer demand and it reduces the amount of cost per part which will maximize profit for the company. Some advantages of a quick changeover are as follows: increase in production capacity; increase in the number of changeovers; reduction in batch sizes; decrease in inventory; reduction in lead times; increase in flexibility to customer demand; and an edge as far competitive advantage.

1.2 Objective and Goals

The objective of this project is to reduce the amount of time required to changeover the S19 production cell at Karma by 50% and improve tasks that affect time in that production cell. A reduction in time will save money, increase productivity and increase competitive advantage along with increasing and customer flexibility. Some goals specified by the Team Sponsor were to reduce the setup time required for the S19 product family by 50% from the current state, by the end of the third week of March. Following the third week of March the team will be required to observe the implementations and record metrics to compare the current state and future state to indicate whether the implementations were successful.

1.3 Scope and Constraints

The scope of this project is constrained to a single production cell regarding a specific product at Karma Machining & Manufacturing; with this in mind the team is only concerned with addressing the machines in the production cell and the areas that influence that production cell, such as the tool room. Any solution that is implemented should be cost effective, and any money spent on solutions should have a return on investment within 3-6 months. The solutions should be standardized so the they are easy to implement and sustainable. The setup times of the S19 product family should be reduced by at least 50%. Solutions are also constrained by the number of workers available in the work cell, and the amount of space available in each production cell and/or machine shop.

2.0 CURRENT STATE

2.1 Setup Analysis

Table 1: Setup Times for Robo Cop

	Setup Times: Robo Cop		
	Operation	Time (Minutes)	Percentage of Setup
80	Troubleshooting	96.77	34.6%
80	Adjust G-code	51.8	18.5%
80	Prepair and Machine Part	39.22	14.0%
80	Tooling (Gather, Prepair and Touchoff)	35.12	12.6%
20	Change Speeds and Feeds	21	7.5%
20	Inspection	16.5	5.9%
20	Motion	13.55	4.8%
	Total Time	279.4	

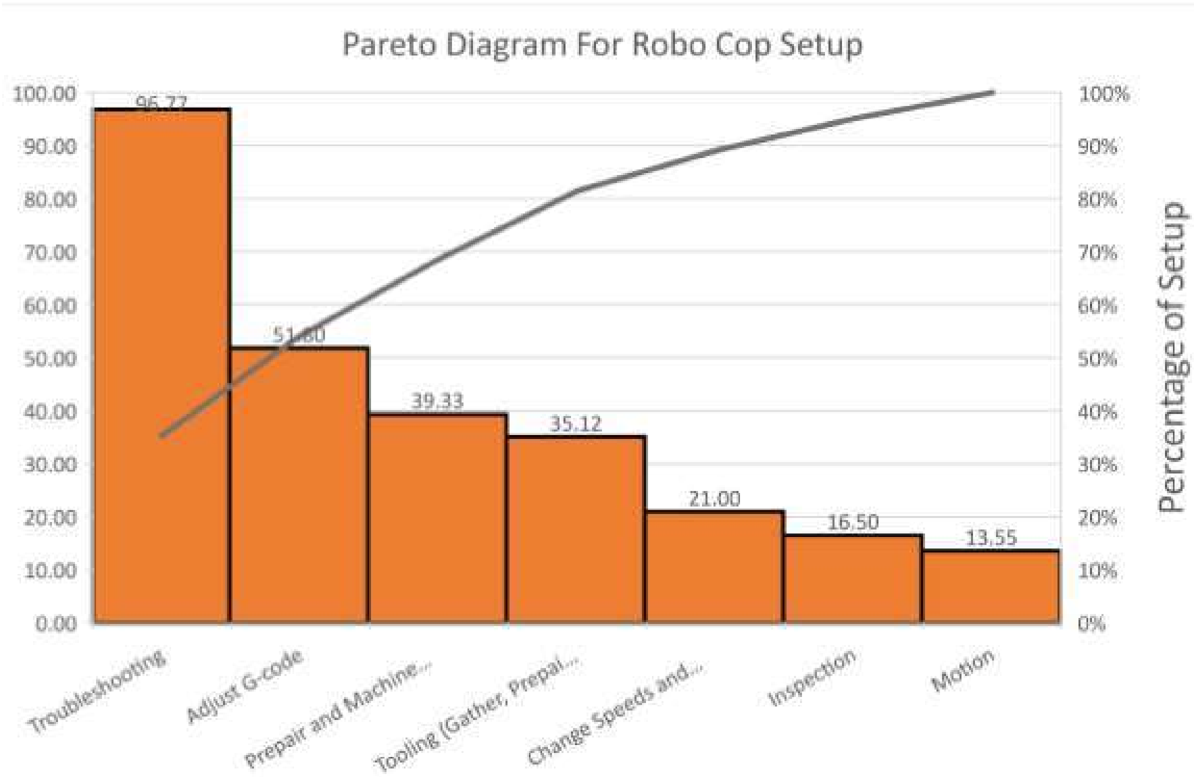


Figure 1: Pareto Diagram for Robo Cop Setup

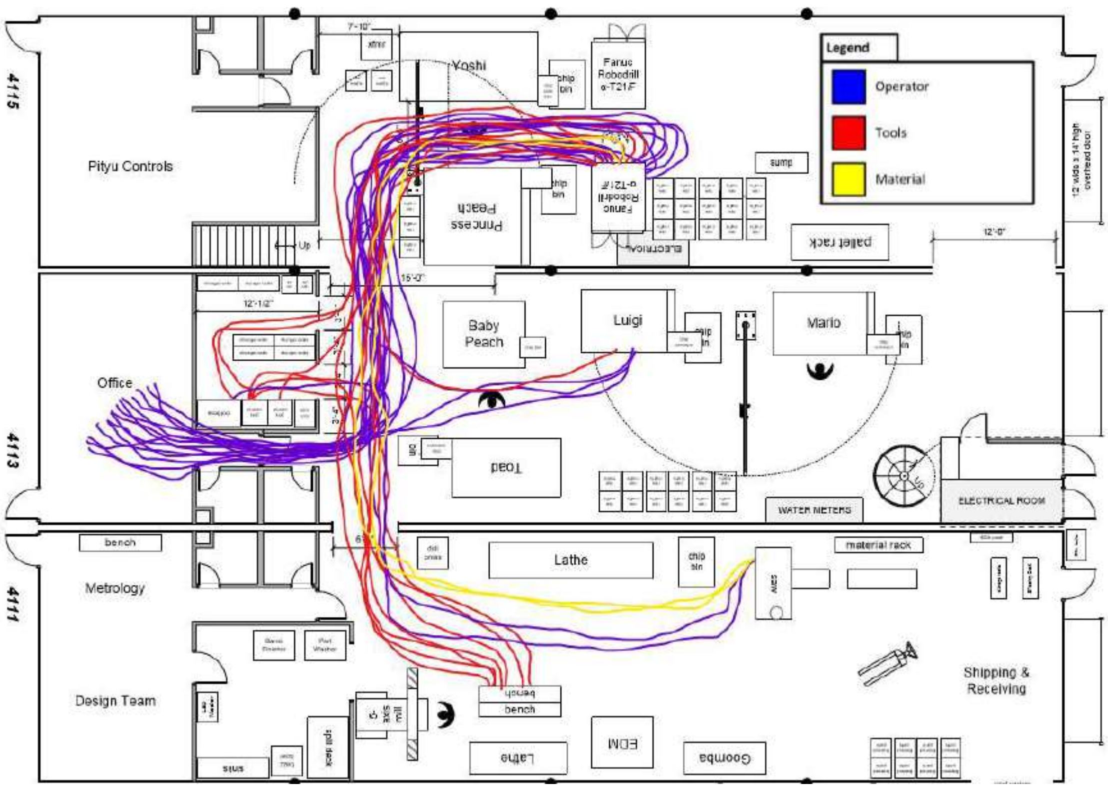


Figure 2: Spaghetti Diagram for Robo Cop Setup

A setup study that was conducted, which analyzed a square part that required two operations. This was done on the "Robo Cop" CNC machining center. When the team arrived, the vises were setup, but all other aspects of the setup was not ready. Throughout the setup, four defects were machined before a successful part was created. The parts deemed as defects had surface finish problems, overlap flaws and sizes that weren't within tolerance. These were mostly troubleshooted by contacting the G-code programmer, he would either change the G-code or suggest different speeds and feeds.

Troubleshooting accounted for 34.6% of the setup. There were multiple errors with the part including surface finishes, overlap errors and problems with part tolerances. In order to correct many of these errors, the G-code had to be changed to adjust speeds, feeds, tool paths and tool offsets. These G-code adjustments took up 18.5% of the setup. There was a lot of back and forth between the operator and G-code programmer, this is shown in the spaghetti diagram (figure 2) by multiple trips to the office.

Preparing and machining the part is a difficult process to reduce the time for. This part of the setup included loading and unloading the part, loading the program into the machine, dry runs and the actual machining of the part. This time was increased because of the number of defects. The time is around 10 minutes per part, and this is an acceptable value.

Preparing the tooling took 12.6% of the setup, with most of this time allotted to changing the tools on the tool holder. One of the reasons changing the tools took so long was because the operator had no tool holder at his workstation, because of this he had to bring his tools to a bench vise located across the shop. This could have been avoided by mounting the tool holder at the machine's work bench. Another time-consuming aspect was finding the tools, the operator had to look in multiple places including other machines.

The preparation of tooling was more problematic during other setups, especially for lathe setups. On the lathe setup, finding and preparing tools would sometimes take over half the setup time. This is partly because there are more components to lathe tools and it takes longer to dial in drills and boring bars, but a large part of the extra time can be traced to the tool room organization as well. For the setup observed on Robo Cop, the operator was able to find some tools that were already prepared for machining. This lead to a significant reduction of tool preparation time when compared to the lathe setups. However, it is unreliable to expect to find tools that are prepared for the setup every time.

Changing speeds and feeds was not part of the 80% that was focused on in the pareto analysis, but this could have been completely avoided because it was due to a missing tool. The G-Code called for a carbide drill, but the operator couldn’t find this in the tool room. As a solution to the missing tool he opted to use an HSS drill instead. This was a viable solution, however the operator had to change the speeds and feeds for every drilling operation. This was done on the machine interface and was very inefficient.

The inspections include both final inspections and periodic inspections during the machining of the part. The 5.9% was increased because of the number of defects, with each defect requiring periodic and a final inspection. Inspection is a necessary part of machining and it was not part of the 80% focus, so there were few implementations regarding inspections. The main implementation that will help to improve the inspections are the organization changes that were done to the quality control tool area.

2.2 Tool Room

The tool room organization posed an issue regarding the efficiency of tasks throughout the entire machine shop; as seen in Figure 3 the tools are unorganized with no way to know exactly where each tool belongs, how many there are or if any of them are missing. The organization of the tool room causes the operators to spend too much time looking for tools.

Figure 3: Current Tool Room State

Figure 4 shows randomly assorted tools and material sitting on a cart taking up space. Piles of unorganized material and tools reduces the efficiency of changeovers and other tasks in the shop when compared to an organized tool system. These figures also show how carts are being used to hold these tools instead of designated locations on shelves and in drawers. The cart does not provide the necessary organization that a drawer would provide.

Figure 4: Tool Cart

Tool blocks were also a problem in the tool room, because they were unorganized with no designated locations, and there were parts missing that were necessary for assembly, such as missing bolts, coolant components and O-rings. A large concern that the team had was the missing assembly parts, because it causes the operators to search for more parts then they originally had to.

The Team Sponsor wanted Pseudo Techs to understand what the process of searching and collecting all the tools and necessary information (speed, feed and depth of cut). To better understand the process of the operators, members of Pseudo Techs gathered all the tools and information for one of the setups. Ideally, the tool room should be designed with ease of use, so an unexperienced individual can find any tools they need with no issues. The tool room experiment proved that this wasn't the case. Table 2 shows the time it took for two team members to gather the tools and necessary information. The average time for these two trials was 42.6 minutes. The longest tasks completed during this experiment was searching for tools. This experiment made it obvious that the tool room should be an area of focus when we start making implementations.

Table 2: Tool Room Exercise Results

Tool Room Exercise		
	Student 1	Student 2
Time (mins)	29.5	55.6

2.3 Flow Charts

Pseudo Techs mapped out the flow of a product through the machine shop, and the flow of information and material when a work order comes in. Figure 5 shows the front office flow chart, which shows what happens when a work order is received. Every order that Karma processes will follow the chart in figure 5 more or less, however exceptions can occur; an example of an exception would be an order that is fast-tracked. Figure 6 shows a flowchart for one product in the S19 product family, in this flowchart the heat treatment takes most of the time because they must ship the products to the heat treatment and then they must ship it back. Typically, the flowchart will change a bit depending on the product, for example many of the other products that Karma does will not have to be heat treated so that would be removed from its flowchart.

Front Office Flow Chart

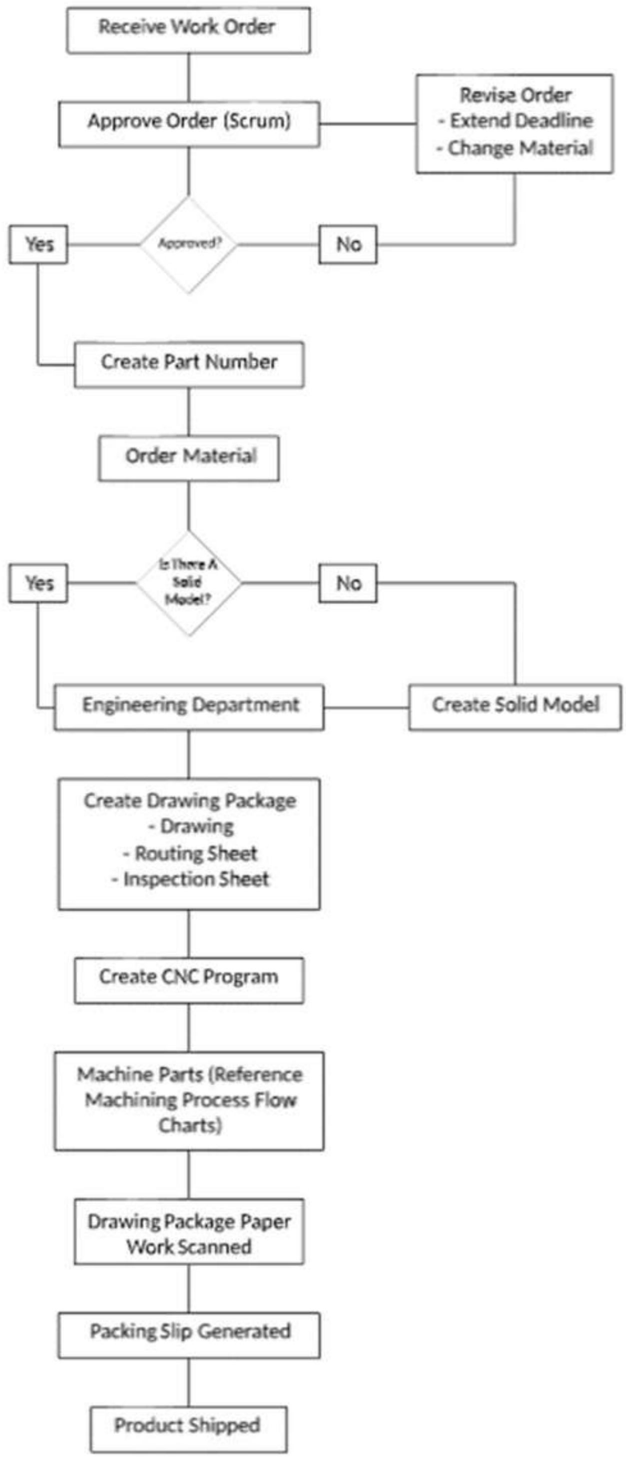


Figure 5: Front Office Flow Chart

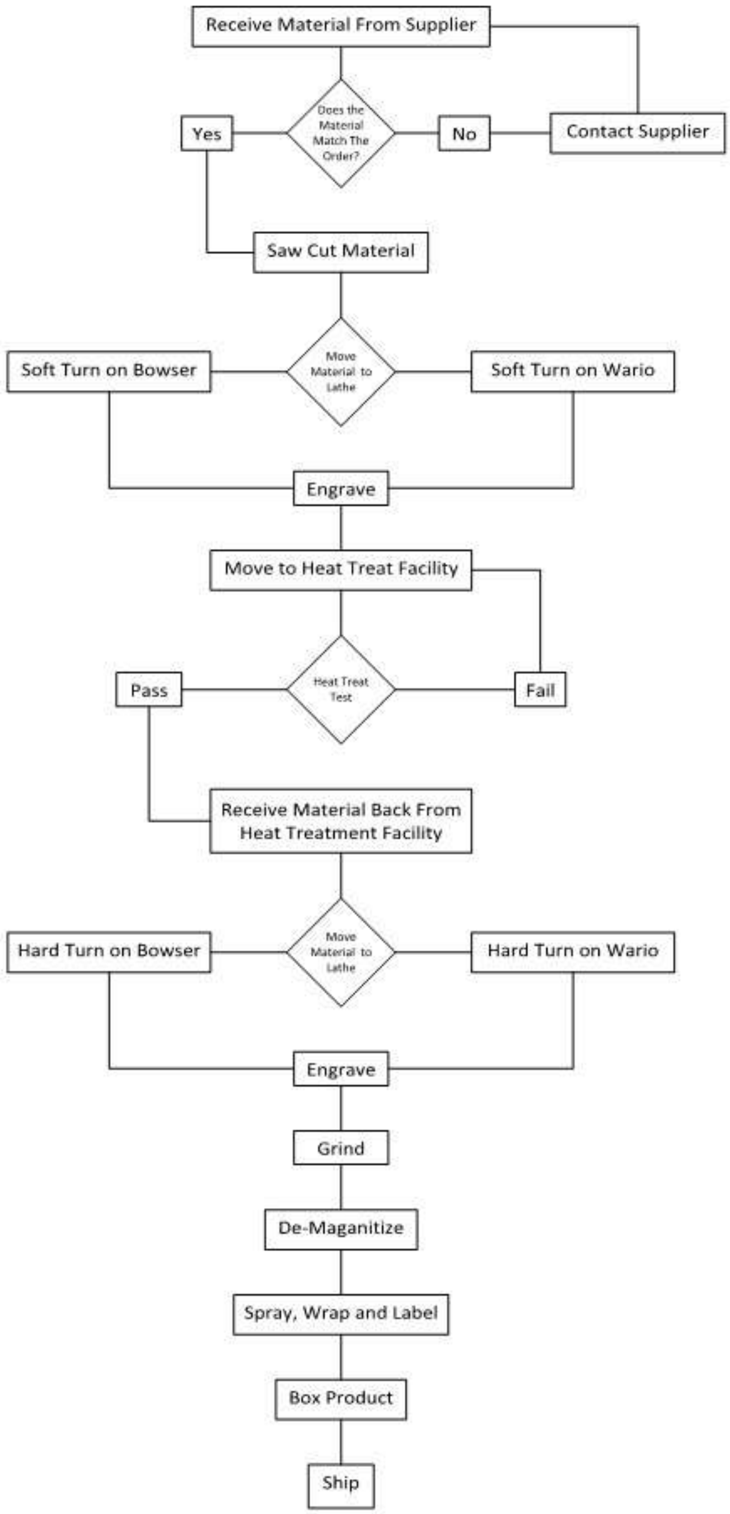


Figure 6: Product Flow Chart

2.4 Operator Input

Operator input is a very important tool used to understand some of the problems that are present in the machine shop. Since they know their job better than any outside source, they were able to offer many common problems and recommend some solutions. Some common problems that were mentioned multiple times were workbench standardization, tool room organization and program consistency.

Workstations were not standardized in the machine shop; tools are scattered and unorganized with no way to know if tools are missing or where they are. There were no standards for replacing tools after you are done using them. Allen keys often go missing, especially the ones that the operator needs. There were many tools that were located at a workbench even though they are seldom used.

Operators commonly noted frustrations regarding the tool room and tool organization. The unorganized state of the toolroom causes setups to run longer and creates a stressful environment for the operators. The toolroom should be an area that operators spend very little time in, especially because the customer is paying for them to machine parts and not look around the tool room.

Some operators mentioned a problem with program consistency regarding speeds and feeds, and sometimes the wrong insert is listed. The most obvious concern that all the operators mentioned was the organization of the tool room; missing tools and inserts, lack of traceability and labels on tools was a large concern. When asked how long setups usually take most operators were listing times in excess of 2 or more hours because of the time it takes to find tools, however in the first setup study an observation was that the most amount of time was consumed during troubleshooting and not tool searching. However, in the unofficial setup study problem that was run into was missing tool problem it was clear that searching for tools was a larger problem then made obvious by the first setup study.

3.0 IMPLEMENTATION

3.1 Implementation Approach

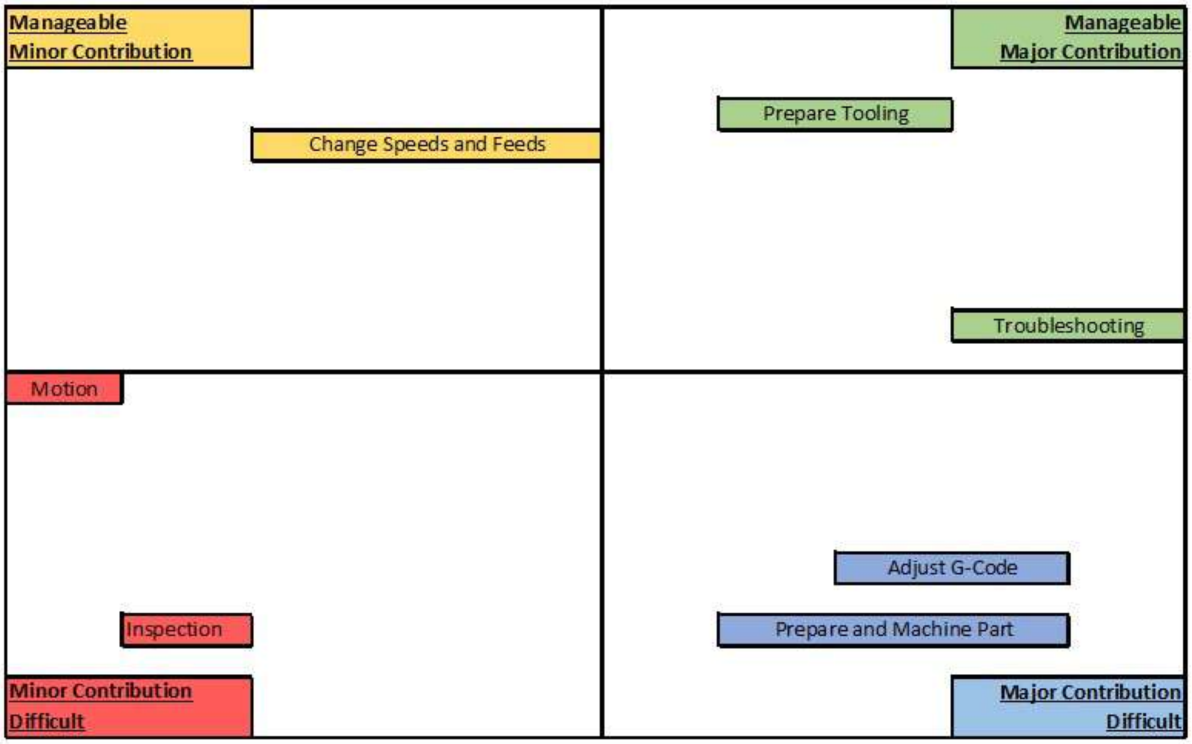


Figure 7: Quadrant Chart for Robo Cop Setup

A Quadrant chart (Figure 7) was created in order to breakdown the tasks based on their contribution to the setup time and based on how hard it would be to implement a solution when considering constraints such as time and cost. The pareto diagram identified tasks that should be worked on; however, it did not identify if those tasks could be worked on. The quadrant chart allowed those tasks to be quantified into a category of manageability. The least difficult to deal with items with the biggest impact on the setup time is put towards the top right of the chart, while the most difficult with the least impact to setup time is put towards the bottom left. The purpose of constructing a quadrant chart is that it is a way to visualize which aspects of the setup can and should be focused on.

3.2 Internal Tasks vs External Tasks

Table 3: Proposed Internal vs External Times

Proposed Internal vs. External Times: Robo Cop		
Operation	Time (Minutes)	External/Internal
Troubleshooting	96.77	Internal
Adjust G-code	51.8	Internal
Prepare Part and Machine Part	39.22	Internal
Tooling (Gather, Prepair and Touchoff)	35.12	External
Change Speeds and Feeds	21	External
Inspection	16.5	Intrernal
Motion	13.55	External
Total Time	279.4	
Proposed Total Internal Time	204.29	
Proposed Total External Time	69.67	

For the Robo Cop current state setup, every task was considered internal because each task started after the last part of the previous production run was machined. Whenever possible, external times should be converted to internal times by completing these tasks during the previous production run. This is the most cost-effective way to reduce setup times because no additional resources need to be implemented. Table 3 shows a reduction of setup time by over an hour; this is done by completing tasks before the last production run is complete. In order to convert these tasks into external times, setup kits can be implemented. These kits will contain all the tools, inserts and any items that are needed to complete a job. The setup kits should reduce having to look for and prepare tools, it also prevents issues like the last-minute change of drills, and the motion of walking back and forth to the tool room.

3.3 Setup Kits

Implementing setup kits is the main way that internal setup times will be converted to external times. The set-up kits will include all the necessary tools, inserts and other equipment needed for the upcoming job, and they will be in the tool room for ease of access; not only will this help reduce the set-up time, but it will make the operators job less stressful. Thereby, reducing the operator movement and the necessity to search for the right tools and inserts.

The set-up kits should be created by the programmer because he knows all the tools necessary to use his programs and therefore, he knows all the tools and equipment needed for the setup. This is beneficial because it converts some internal times to external times and removes some unnecessary wastes that were commonly observed.

3.4 Troubleshooting Guide

The troubleshooting was the largest chunk of time consumed during the setup, taking up 34.6% of the time. Based on this, it was obvious that there should be a larger focus on resolving this issue initially.

In an attempt to get the first good part, multiple defective parts were produced. The operator had to communicate with the programmer in the office on multiple occasions to try and figure out how to troubleshoot the problem. One defect was a result of bad surface finish and this was eventually solved by changing the feed rate, which was communicated to the operator by the programmer in the front office. There are quite a few wastes present during this portion of the setup because the operator was constantly moving back and forth between his workstation and the front office; also, the programmer is often busy tending to other tasks in the office or the machine shop working with other operators, so he was not always available to help the operator troubleshoot the setup. In order to alleviate this problem, it was determined that a standardized troubleshooting guide will most likely help the operators so they can reference it when necessary. To find the full troubleshooting guide please refer to Appendix A.

In Figure 8 below you can see a sample of the troubleshooting guide; in this sample you can see the common causes and solutions regarding chip breaking problems on turning operations. As an example, the operator could be having problems with long snarled chips that wrap around the workpiece or chuck during turning. Instead of the operator searching for the programmer in order to confer with him about how to resolve the problem, the operator can reference chip breaking in the turning section of the troubleshooting guide. This will give them an idea of the kind of problem they are dealing with and some direction of how they can solve it. Hopefully the operator can pair the information from the troubleshooting guide to his past experiences in order to devise a solution.

Each machine should have a troubleshooting guide present so that any operator can refer to it at any time. A general guide for multiple different operations was created for the troubleshooting guide; however, each machine will require different troubleshooting criteria. Based on this information a troubleshooting guide that was as universal as possible and a user friendly excel spreadsheet was submitted to Karma Machining & Manufacturing so that they may edit it as they see fit, in order to accommodate different machines and requirements. In figure 9 you can see an example of a tag that would be used to bind the troubleshooting pages together and locate it to a machine. The tag will display what machine the troubleshooting guide belongs to, so if it gets misplaced it can be returned to its machine. This makes the troubleshooting guides traceable and intuitive. All pages of the troubleshooting guide should be laminated because they will be used in a machine shop where the operator's hands or gloves are often dirty from grease, coolant, etc. The laminated pages will prevent the guide from becoming worn down or dirty. In figure 10, you can see a sample page from the troubleshooting recommendations; the purpose of this page is to give operators an option to request additions to the troubleshooting guide when they run into problems that are not already in the guide. These additions can be added to all the troubleshooting guides for other operators if necessary or they can be added to the relevant ones where a problem like that may occur again. This is beneficial to future troubleshooting at that machine and beneficial to others who may run into the same problem.

Turning

Chip Break Troubleshooting

Problem	Cause(s)	Solution(s)
Long unbroken and snarled chips that may or may not wind around the workpiece 	Low feedrate, and/or high cutting speed	Increase feedrate, decrease cutting speed use a chip breaking insert, use precision coolant tooling if possible
	Depth of cut too short for the selected insert geometry	Increase depth of cut or choose an insert with different geometry
	Insert nose radius is too large	Select an insert with a smaller nose radius
	Incorrect entering lead angle (lead angle may be too large)	Select a tool holder with a smaller lead angle
Very short chips, may stick together. Reduced tool life, or breakages, chip load may be too large 	Feedrate too high based on insert geometry	Reduce the feedrate, or choose an insert that can handle the higher feedrate
	Lead angle too small	Select a tool holder with a large lead angle
	Nose radius may be too small	Select an insert with a larger nose radius

T1 | Turning | Parting and Grooving | Drilling | Boring | Insert Wear

Figure 8: Troubleshooting Guide Sample

Figure 9: Troubleshooting Guide Traceable Tags

Troubleshooting Recommendations			
If you run into problems that are not included in this guide please write them down below so that they may be added to the guide for other operators or in case the problem arises again in the future.			
Date	Machine	Description	Initial

Figure 10: Troubleshooting Recommendations

3.5 Tool Room

3.5.1 Tools

The tool room is utilized in every setup, so it is important that use of this area is as efficient and user friendly as possible. The current state of the toolroom was an area with a lot of room for improvement, it was unorganized with hardly any standardized systems to maintain organization. A proper standardized system would go a long way in improving the organization and efficiency of the entire machine shop.

One of the recommendations for the toolroom was standardized tool labeling system. Figure 11 shows naming convention that can identify the type of tool and its location. The naming convention is designed to group similar tools with each other (for example, all the boring bars will be stored in the same toolbox drawer), being ordered from smallest to largest size. The naming convention will be printed on labels that will be placed inside the toolbox drawer with the drawers being clearly labeled from the outside. Figure 12 shows one possible example of tool organization in the toolbox.

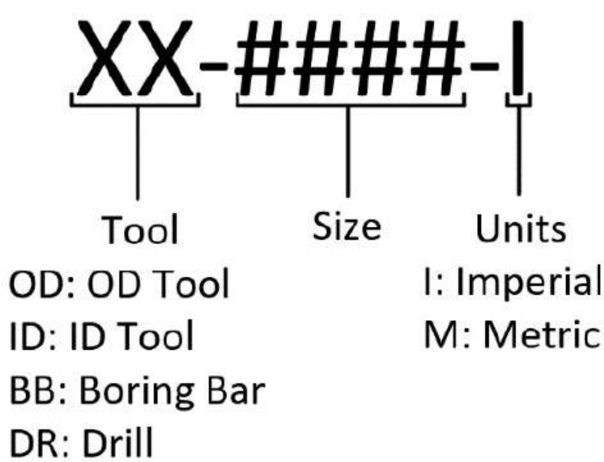


Figure 11: Tool Identification Naming Convention

The tools are separated using dividers so it is clear how many tools should be present and where they belong according to their labels. The cards in place of the missing tools identify where the tools are currently being used, this adds traceability to the system. These cards should be used every time an operator takes a tool from the toolroom. This also helps let other operators know when a tool is in use, so they do not need to search through the toolroom looking for a tool that they won't find. Another benefit of the card system is if a tool slot is empty with no card, this clearly indicates that a tool is missing.

Figure 12: Recommended Toolbox Organization

3.5.2 Collets

To rectify the collet organization problem a 3D printed model was designed so that the collets can be organized according to size. Figure 13 shows a 3D model of the design that was recommended to Karma. It is going to be printed in three parts, one body then two supports. The rods in the design help prevent misplacing the collets, however, it does not remove the problem altogether because large collets can still be places in smaller locations. The sizes will be identified where the collets belong so there are two preventative measures to misplacing the collets instead of one.

Figure 13: 3D Printed Collet Holder

Allen keys posed a problem in the machine shop because there was no way to make sure they went back where they were supposed to go; the reason this is a problem is because it causes Allen keys to be misplaced and go missing. This holder, like the collet one, is going to be 3D printed in the shop as you can see in figure 14. One of the reasons it is going to be 3D printed is because if Karma ever needs more of the holders or needs to modify them, they can easily change it, so it is better suited to fit their needs. The holders should be hanged at the operators' workstations. The holes in the holder are designed in such a way that the larger Allen keys won't fit in the smaller holes and the smaller Allen keys will slip when placed in the larger holes. This ensures that the Allen keys are placed back in their proper location when the operator is done with them.

Figure 14: Allen Key Holder

3.5.3 Toolholder Organization

The team sponsor had the Pseudo Techs perform an experiment in the toolroom by taking one of the toolholders and trying to find all the equipment necessary to assembly it. Some of the equipment was missing, such as bolts, set screws, coolant plugs etc.; these missing items made it impossible to assemble a toolholder, which makes the problems that operators experience everyday apparent. For a complete implementation report regarding toolholder organization please refer to Appendix C.

In figure 15 below you can see an overview of what the team recommended for toolholder organization. A comparison can be made between figure 15 and figure 16, figure 16 shows the current state of the toolholder shelf organization in which the tool holders are randomly placed on the shelf with no labels or designated locations. Each toolholder should have a designated location with a label identifying a name for each toolholder and where each toolholder belongs as you can see in figure 19. Above each toolholder will be four small bins suspended by 2 3D printed cradles shown in figures 15, 17, and 18. Each bin will be labeled with the items that belong in each bin, and the 4 bins will have all the items necessary to assemble the toolholder below it. The cradles will be suspended and attached to the plywood above it using wood screws. Refer to figure 18 to see how the bins are assembled and attached to the shelf. When a toolholder is taken, a card that identifies which machine it is located at should be used as a placeholder so the items in the bins and toolholder can be traced. As an example, figure 19 shows an empty tool holder location and a card with a picture of Wario used as a place holder; the Wario card identifies that the tool holder is located at the Wario machine, which is what Karma calls one of their CNC machines.

The inventor assembly was modeled around dimensions that match specific bins found at Home Depot. Theses bins were recommended to be used in the organization of the toolholders. Refer to figure 20 to see the recommended bins.

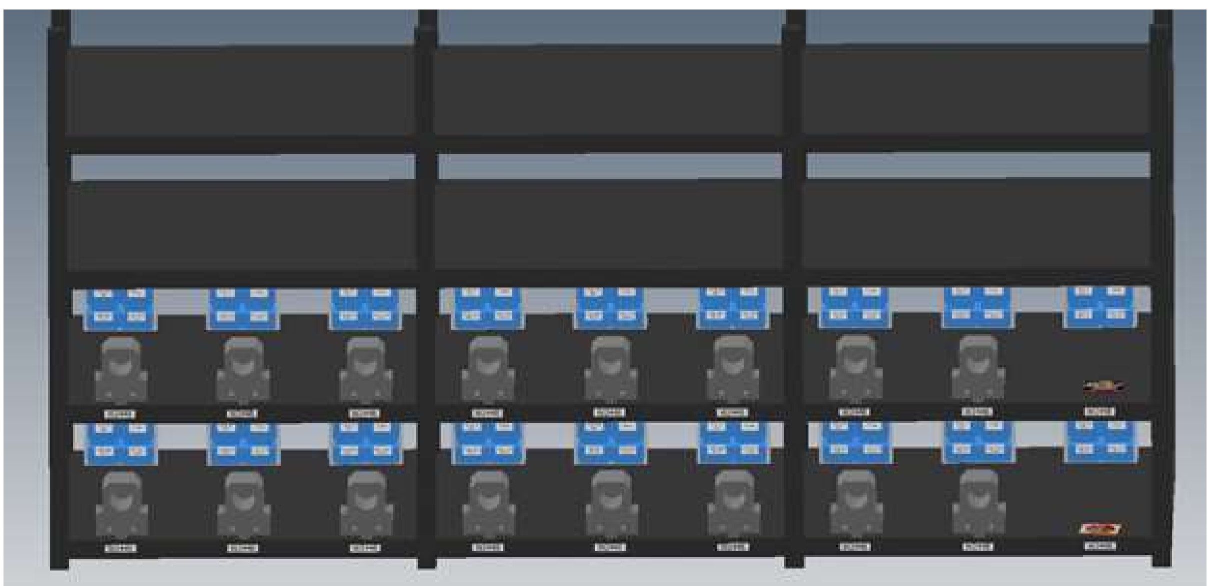


Figure 15: Recommended Toolholder Shelf Organization

Figure 16: Current Toolholder Shelf Organization

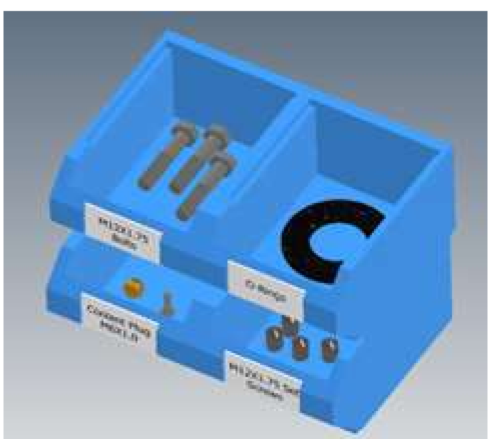


Figure 17: Bin Items and Labels

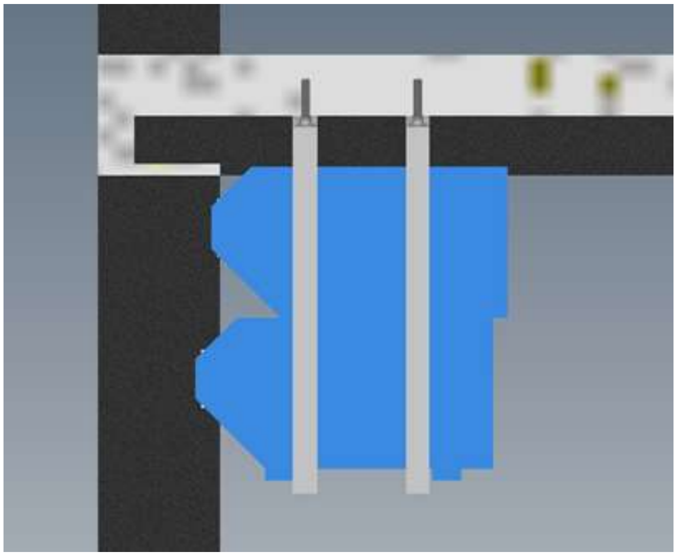


Figure 18: Bin Locating

Figure 19: Empty Tool Holder Location and Label Convention

Home > Tools > Tool Storage > Small Parts Organizers > 1000752010

HUSKY Stackable Click Bins in Grey (4-Pack)

Model # 17197119 | Store SKU # 1000752010

Figure 20: Recommended Bins from Home Depot

3.6 Miscellaneous Recommendations

3.6.1 Slatwall

A beneficial implementation for machine shops is Slatwall because it is very flexible to any environment. Slatwall is a great way to utilize empty space and vertical space to organize a machine shop. Since missing tools and designated tool locations was such a large problem observed in the machine shop, Slatwall was a good remedy to the problem for several reasons. Slatwall is compatible with tool shadows. The shadows can be used to make sure the tools remain in their proper location; shadows also act as a mechanism that tells you when a tool is missing or in use. Karma also owns 3D printers so they can accommodate many different tools and configurations to fit on the Slatwall. Karma can use their 3D printers to print hooks that will be used to locate tools and accessories against the Slatwall.

Slatwall also cleans up the tool room by utilizing space that wasn't initially available to be used; this will clean up the tool racks and open up space to be used more efficiently. Slatwall makes it a lot easier to find the tools you are looking for because it's presented in a way that makes everything clear and easy to see. The new installed Slatwall in the tool room can be seen in figure 21, the same size Slatwall is featured on the opposite side of the tool room as well to utilize more space.

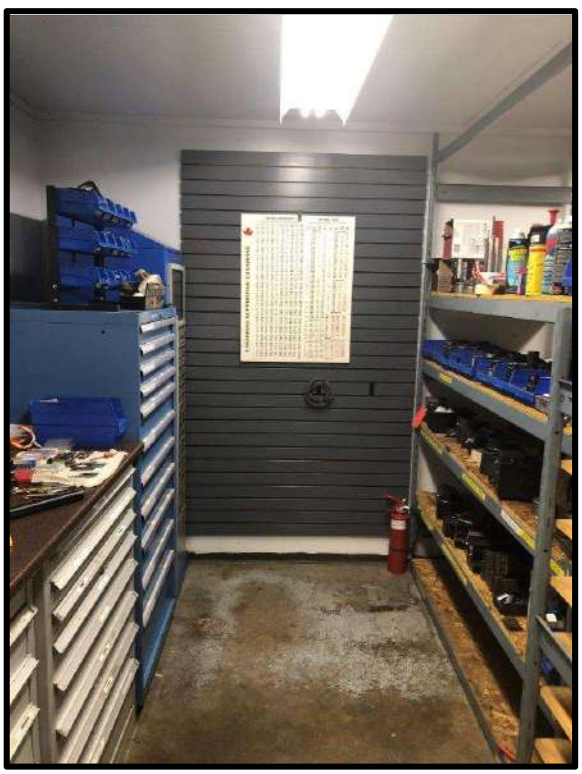


Figure 21: Slatwall in the Tool Room

3.6.2 Workstation Tool Standardization

A discussion was conducted with 3 different operators at Karma to figure out which tools they used frequently at their workstations. In figure 22 you can see a list of relevant tools that the operators claimed they used on a daily or semi-daily basis. In order to mitigate wastes that go into searching for these tools or going to grab them it was recommended that these standard tools be present at each operator's workstation.

Quality Control

- Calipers
- Micrometers (0-1",1"-2",2"-3" and 5"-6")
- Dial Indicator
- Go, No Go Gauges
- Feeler Gauge

Finishing Tools

- Files
- Deburr Tools
- Scotch Brite

Setup

- Torque Wrench/Screwdrivers
- Allen Keys
- Torx Keys
- Snipe
- Chuck Jaws
- Collet Chuck Wrench

Other

- Sharpie and Paint Pen
- Cordless Drill

Figure 22: Common Tools Relevant to Operator's Workstation's

4.0 FUTURE STATE

4.1 Predicted Outcome

Table 4: Predicted Setup Times

Prediction for Setup Times: Robo Cop			
Operation	Time (Minutes)	Percentage of Reduction (%)	Reduction (Minutes)
Troubleshooting	96.77	75-50	72.58-48.39
Adjust G-code	51.8	75-50	38.85-25.9
Prepare and Machine Part	39.22	0	0
Tooling (Gather, Prepair and Touchoff)	35.12	100	35.12
Change Speeds and Feeds	21	100	21
Inspection	16.5	0	0
Motion	13.55	100	13.55
Total Time:	**279.4**		
Total Reduction:			**181.1-143.96**
Predicted Time with Implmentaions:			**98.5-135.44**

Without a study of multiple setups, it would be impossible to assign an accurate value for how much a troubleshooting guide will improve the setup time. Due to the uncertainties regarding the effectiveness a range of 75%-50% was predicted. This is based on the operator solving the problem with one or two attempts by referencing troubleshooting guides, rather than the four attempts that were made during the current state analysis. Since there are problems and solutions that are clearly laid out in the troubleshooting guide, there will be reduction in attempts because the operator will likely spend less time experimenting with wrong ideas.

The tooling has 100% reduction because this time was converted to external time using the setup kits. Since the majority of motion was in relation to gathering tools, the setup kits will reduce this time by 100% too. The errors of having to change the speeds and feeds based on the last-minute change of drills will also be 100% reduced because the setup kit will provide the proper drill for the operation. The setups kits allow all three of these tasks to be converted to external times.

$$\%Reduction = \frac{Total\ Reduction}{Total\ Time} * 100 = \frac{181.1 mins}{279.4\ mins} * 100 = 64.8\%$$

$$\%Reduction = \frac{Total\ Reduction}{Total\ Time} * 100 = \frac{143.96\ mins}{279.4\ mins} * 100 = 51.5\%$$

$$Cost\ Saved = {}^{Cost}/_{min} * Time = {}^{\$2}/_{min} * 181.1\ mins = \$362.2$$

$$Cost\ Saved = {}^{Cost}/_{min} * Time = {}^{\$2}/_{min} * 143.96\ mins = \$287.92$$

The predicted setup reduction of 51.5%-64.8% does achieve and surpass the goal of 50%. The predicted monetary savings is $287.92-$362.2 for each setup. This means that the minimal costs of the implementations should have a return of investment after one setup.

4.2 Recommendations

4.2.1 Improvement Analysis Recommendations

Pseudo Techs recommend that Karma revisit the data collected in this report after 6 months to compare data against improvements. Since there is a learning curve to improvements it isn't productive to measure results right away, improvements take time to become noticeable. Therefore, it is recommended that experiments and time studies be conducted over the course of, or after 6 months to compare to the data in this report. Hopefully after new data is collected it will resemble the numbers predicted in section 4.1.

4.2.2 Troubleshooting Guide Recommendations

Pseudo Techs recommends that Karma keep updating the troubleshooting guide as relevant information is discovered, or as recommendations from the operators come in. When recommendations from operators come in, they should be added to the guide because they can help other operators who may face the same problem in the future, and they can also help operators who may run into the problem again. However, if the troubleshooting guide gets neglected then the operators may return to old habits and experiment with solutions that may not give them adequate results, or they may waste time consulting with other workers for solutions.

4.2.3 Future Improvements

Based on the predictions made about future state data, which can be seen in figure 23 and table 5 below, troubleshooting should still take up the largest amount of time during a setup. Based on these results Pseudo Techs recommends that each of the operations listed should be examined and divided into more specific tasks. Once more specific tasks are identified, a new pareto diagram can be generated and analyzed and the new tasks can be observed and improved based on the results of the new pareto analysis. This will allow Karma to broaden their scope and make improvements by picking apart smaller wastes that occur within larger operations or tasks. There should be a constant cycle of analyzing new data based on new measurements and making continuous improvements along the way.

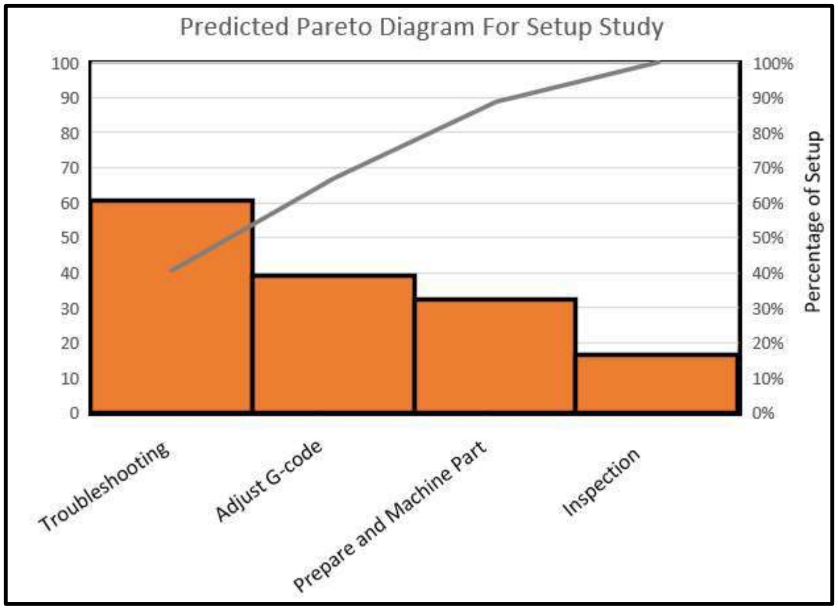


Figure 23: Predicted Pareto Diagram

Table 5: Future State Pareto Data

	Future State Pareto: Robo Cop		
	Operation	Time (minutes)	Percentage of Setup (%)
80	Troubleshooting*	60.48	40.71
	Prepare and Machine Part	39.22	26.40
	Adjust G-code*	32.38	21.80
20	Inspection	16.50	11.11
	Total Time:	148.58	

*Based off 62.5% Reduction

5.0 CONCLUSION

With some implementations starting to be put into place, improvements have been noticed immediately. However, currently there is no data to measure the success of the project. With the predicted times based on the setup study, it is expected that the 50% requirement will be met and exceeded. The cost-effective solution and financial benefits associated with the setup reduction will help to increase profits while decreasing customer wait times. This will help Karma have an advantage compared to their competition.

6.0 REFERENCES

Morton, R. (2020, January 21). Free CAD Designs, Files & 3D Models: The GrabCAD Community Library. Retrieved from https://grabcad.com/library/er40-collet-family-1

Sandvik. (n.d.). Troubleshooting. Retrieved from https://www.sandvik.coromant.com/en-us/knowledge/general-turning/pages/troubleshooting.aspx

(n.d.). Retrieved from http://karmamfg.ca/index.php

(2018, December 31). 10 Best Homespun images: Hanging towels, Primitive carrots, Clothespin bag. Retrieved from https://www.pinterest.ca/floweringfelts/homespun/

APPENDICES

APPENDIX A

KARMA

MACHINING & MANUFACTURING LTD.

Troubleshooting Guide

4113 98 St NW, Edmonton, AB
_T6E 5N5_

Troubleshooting Guide, Revision 0, March 2020

Troubleshooting Recommendations			
If you run into problems that are not included in this guide please write them down below so that they may be added to the guide for other operators or in case the problem arises again in the future.			
Date	Machine	Description	Initial

TABLE OF CONTENTS

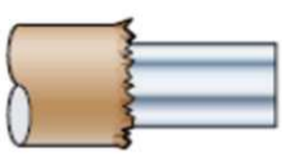
Turning

Chip Break Troubleshooting

Problem	Cause(s)	Solution(s)
Long unbroken and snarled chips that may or may not wind around the workpiece 	Low feedrate, and/or high cutting speed	Increase feedrate, decrease cutting speed use a chip breaking insert, use precision coolant tooling if possible
	Depth of cut too short for the selected insert geometry	Increase depth of cut or choose an insert with different geometry
	Insert nose radius is too large	Select an insert with a smaller nose radius
	Incorrect entering lead angle (lead angle may be too large)	Select a tool holder with a smaller lead angle
Very short chips, may stick together. Reduced tool life, or breakages, chip load may be too large 	Feedrate too high based on insert geometry	Reduce the feedrate, or choose an insert that can handle the higher feedrate
	Lead angle too small	Select a tool holder with a large lead angle
	Nose radius may be too small	Select an insert with a larger nose radius

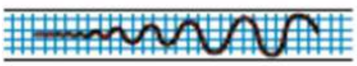
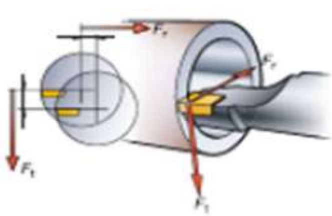
Turning

Surface Finish Troubleshooting

Problem	Cause(s)	Solution(s)
Surface feels "hairy" and does not meet customer specifications	Chips are breaking against the surface of the part	Select insert geometry that guides chips away from part, change lead angle, reduce depth of cut
	Can be caused by notch wear on the tool insert	Select a grade of insert with better resistance to oxidation wear, reduced speed, vary depth of cut
	Feedrate is too high for the insert's tool nose radius (radius is tool small)	Select an insert with a large nose radius, or decrease the feedrate
Formation of burrs at the end of the cut	The cutting edge is too dull, or the feedrate is too low	Use an insert with a sharper cutting edge
	Notch wear or chipping is occuring at chosen depth of cut	Use a tool holder with a larger lead angle, or reduce the depth of cut
	Alternative	Finish the cut with a radius or chamfer when exiting the workpiece

Turning

Vibration Troubleshooting

Problem	Cause(s)	Solution(s)
High radial cutting forces causing vibration  Vibrations or chatter marks which are caused by the tooling or the tool mounting. Typical for internal machining with boring bars.	Lead angle not suitable for operation	select a smaller lead angle
	Insert nose radius is too large	Select an insert with a smaller nose radius
	Flank wear on insert cutting edge	Reduce the feedrate, or choose a higher wear resistance insert grade
High tangential cutting forces casuing vibration 	Chip breaking is too hard	Reduce the feedrate, or choose an insert designed for higher feedrates (different gemoetry)
	Cutting forces too low based on depth of cut (depth of cut too small)	Increase the depth of cut
	Tool is mounted incorrectly	Check that the tool is mounted correctly

Turning

Vibration Troubleshooting

Problem	Cause(s)	Solution(s)
Vibration 	Tool is unstable cause by longer overhang	Reduce the overhang Use a larger bar diamter if possible
Vibration 	Tool clamping is unstable and/or insufficient	Use a longer clamping length on the tool

Parting and Grooving

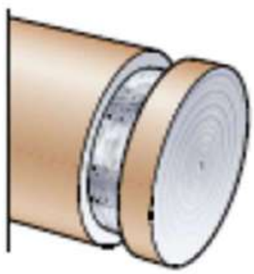
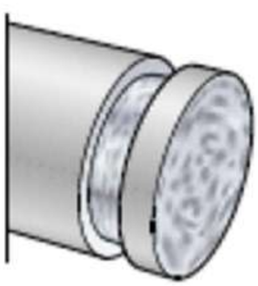
Tool Wear

Problem	Possible Solution	Best Solution
Flank Wear 	Decrease cutting speed	Choose an insert with a better wear resistance grade
Plastic 	Decrease the cutting speed, or choose an insert with a better wear resistant grade	Reduce the feedrate
Crater Wear 	Choose an insert with a better wear resitant grade	Decrease the cutting speed
Chipping 	Reduce the feedrate, or choose an insert with stronger geometry	Choose an insert with a tougher grade
Fracture 	Reduce the feedrate	Choose an insert with stronger geometry
Built-Up Edge 	Increase the cutting speed	Choose an insert with more positive geometry

Note: Please refer to the Sandvik Tool Wear app for an easier to use and more comprehensive guide on tool wear.

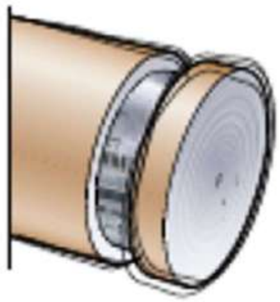
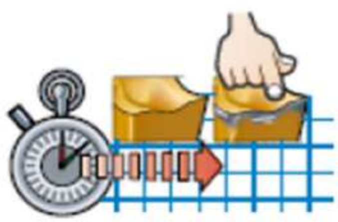
Parting and Grooving

General

Problem	Solution(s)	
Poor surface finish 	Use a shorter or more stable tool	Choose insert geometry with better chip control
	Use precision coolant tooling if possible	Check if cutting speed and feedrate is correct based on guidelines
	Use an insert with wiper geometry	Check if tool setup is correct
Poor surface finish on aluminum 	Select an insert with sharper geometry	Choose insert geometry with better chip control
	Use precision coolant tooling if possible	
Poor Chip Breaking 	Change tool insert geometry	Increase the feedrate
	Use precision coolant tooling if possible	Use dwelling (pecking) if possible

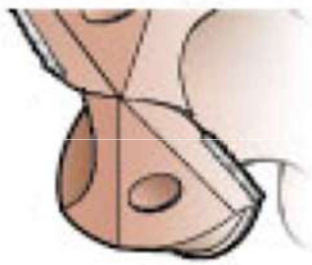
Parting and Grooving

General

Problem	Solution(s)	
Vibration 	Make sure tool setup is stable	Change insert geometry
	Check if cutting speed and feedrate is correct based on guidelines	Check condition of tool and insert
	Use a shorter tool or shorter overhang	Check center height of tool setup
Poor tool life 	Check center height of tool	Check angle between tool and component
	Use precision coolant tooling if possible	Check the condition of the blade, insert could be unstable

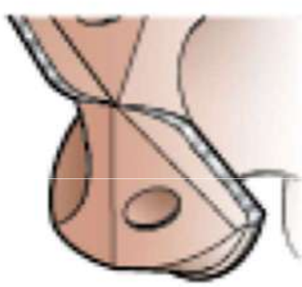
Drilling

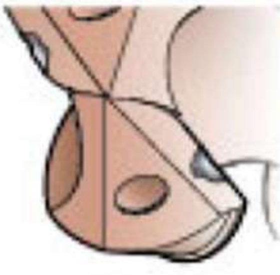
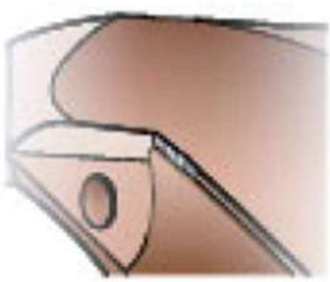
Built-up Edge

Problem	Cause(s)	Solution(s)
Built-up Edge 	Cutting speed is too low (causes temperature at cutting edge to be low)	Increase the cutting speed, or change the insert to a coated grade
	Tool insert cutting geometry is too negative	Select an tool with more positive geometry
	Sticky materials such as aluminum and stainless steels	Increase oil mixture and volume/pressure in the coolant
	Oil mixture in coolant is too low	Increase the oil mixture in the coolant

Drilling

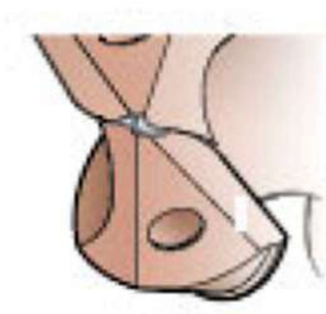
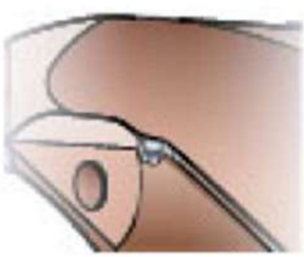
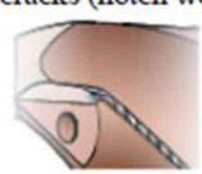
Tool Wear

Problem	Cause(s)	Solution(s)
Chipping on edge corner 	Fixture unstable	Check the fixture (clamps, tool body, etc.)
	Intermittent drilling	Decrease feedrate
	Insuffient coolant	Increase coolant flow if possible, check coolant supply
	Unstable tool holding	Check tool holder
Flank wear on cutting edges 	Cause(s)	Solution(s)
	Cutting speed is too high	Decrease the cutting speed
	Feedrate is too low	Increase the feedrate
	Grade is too soft	Select a harder grade
	Insuffient coolant	Increase coolant flow if possible, check coolant supply

Drilling			
Tool Wear			D3
Problem	Cause(s)	Solution(s)	
Chipping on cutting edge 	Setup is unstable, tool holder, tool or fixture	Check setup	Turning
	Tool wear allowance exceeded	Replace drill	
	Grade is too hard	Select a softer grade	Parting and Grooving
Wear on circular lands 	Cause(s)	Solution(s)	
	Coolant is too weak	Use a neat oil or a stronger emulsion	Drilling
	Cutting speed is too high	Decrease the cutting speed	Boring
	Material is abrazive	Select a harder grade tool	Insert Wear

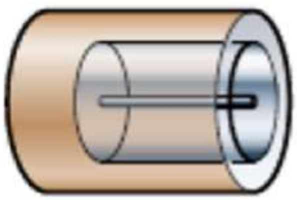
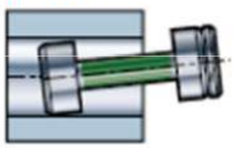
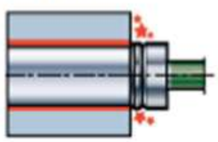
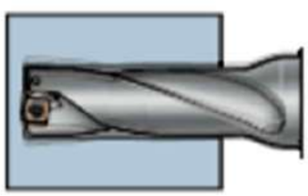
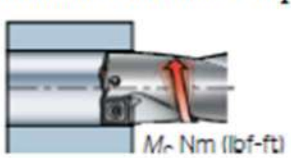
Drilling

Tool Wear

Problem	Cause(s)	Solution(s)
Wear on the chisel edge 	Slow cutting speed	Increase cutting speed
	High feedrate	Decrease feedrate
	Small chisel edge	Check dimesions
Wear due to plastic deformation 	Cutting parameters too high (speed/feed)	Decrease cutting parameters
	Insufficient coolant	Increase collant flow if possible, check coolant supply
	Drill/grade is not suitable for operation	Select a harder grade
Thermal cracks (notch wear) 	Inconsistent coolant	Check coolant supply
		Fill coolant tank

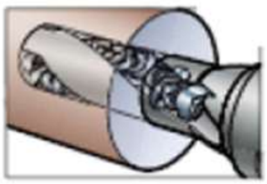
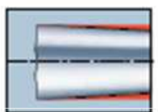
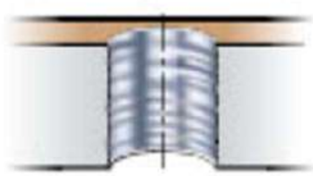
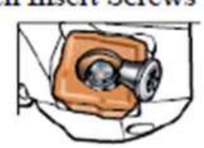
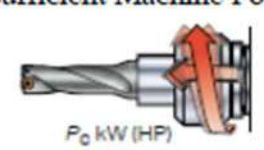
Drilling

Rotating Drill Troubleshooting

Problem	Solution(s)	
Pin in Hole 	Increase coolant flow, clean filter, clear coolant holes in drill	Try a different geometry on peripheral side and adjust feedrate within recommended cutting data
	Shorten drill overhang	Use a lower feedrate during the first 3 mm of the hole depth
Oversized Holes 	Increase coolant flow, clean filter, clear coolant holes in drill	Try a tougher geometry on peripheral side (keep center insert)
Undersized Holes 	Increase coolant flow, clean filter, clear coolant holes in drill	Try a tougher geometry on center side and a light cutting geometry on peripheral side
Vibrations 	Shorten drill overhang. Improve the workpiece stability	Reduce the cutting speed
	Try a different geometry on peripheral side and adjust feedrate within recommended cutting data	
Insufficient Machine Torque 	Reduce Feed	Choose a light cutting geometry to lower the cutting force

Drilling

Non-rotating Drill Troubleshooting

Problem	Solution(s)	
Chip Jamming in the Drill Flutes (caused by long chips) 	cCheck geometry and cutting data recommendations	increase coolant flow, clean filter, clear coolant holes in drill
	Reduce feed within recommended cutting data	Increase cutting speed within recommended cutting data
Hole not Symmetrical 	Increase coolant flow, clean filter, clear coolant holes in drill	Shorten drill overhang
		Try a different geometry on peripheral side and adjust feedrate within recommended
Poor Tool Life 	Adjust higher or lower cutting speed depending on type of wear (refer to Sandvik Tool Wear app or Insert Wear page in this troubleshooting	Choose a light-cutting geometry to lower the cutting
		Increase feedrate
Bad Surface Finish 	Important to have good chip control	Reduce feedrate and/or cutting speed
	Increase coolant flow, clean filter, clear coolant holes in drill	Shorten drill overhang, improve the workpiece stability
Broken Insert Screws 	Use torque wrench to fasten the screw together, apply Anti seize	Check and change insert screw on a regular basis
Insufficient Machine Power 	Choose a light cutting geometry to lower the cutting force	Reduce the cutting speed
		Reduce the feedrate

Drilling

Chip Evacuation

Chip Evacuation	Solution(s)
	Ensure correct speeds/feeds are being used, and correct drill geometry
	Ensure chips follow the guidelines in the figure at the bottom of this page. If chips do not resemble the guidelines, then refer to the first solution in chip evacuation
	Increase coolant flow and pressure if possible
	Built-up edge can cause unwanted chip formations

Note: If none of these solutions work, peck driling may be used.

Excellent   Acceptable   Not acceptable

Boring		
Vibration		
Solution(s)		
Increase entering angle	Decrease lead angle	Select an insert with a smaller nose radius
Increase depth of cut for finishing operations	Decrease depth of cut for roughing operations	Decrease cutting speed
Implement step boring	If possible and/or applicable choose a 2-edge rough boring bar	Choose an insert with light cutting geometry and grade
Ensure workpiece is clamped properly	Use dampened tool if possible	Decrease overhang if possible
If long overhang is necessary use dampened tools if possible	If long overhang is necessary use large diameter bar if possible	Ensure correct torques were used in tool assembly
Ensure tool was assembled properly	Decrease cutting speed	Decrease feedrate
Note: Please refer to the next page for a visual representation of the solutions listed above.		

B1.1

Entering angle

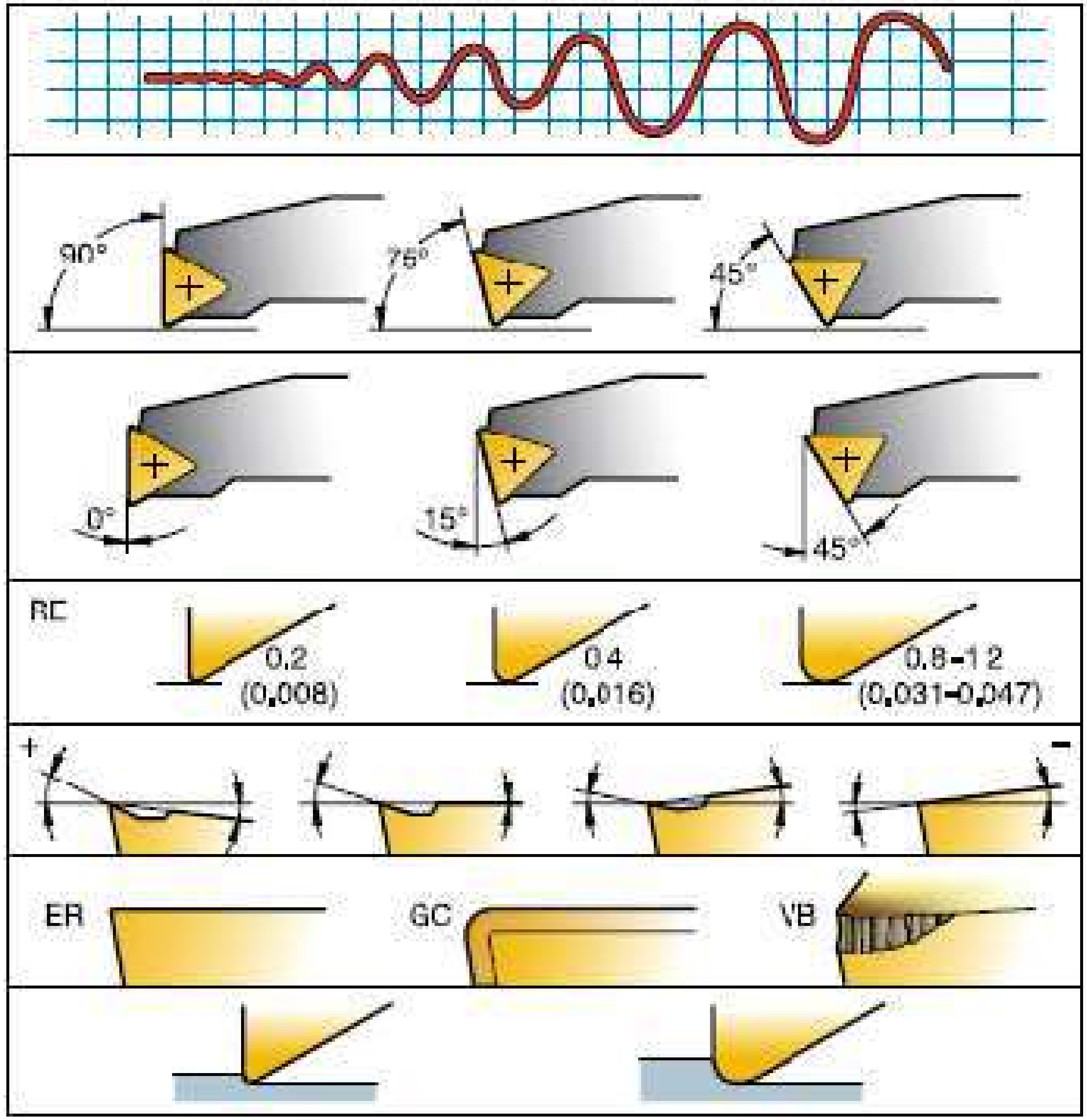
Lead angle

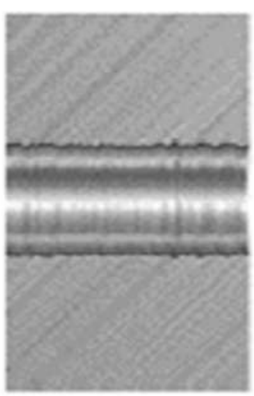
Corner radius

Micro and macro geometry

Edge design

Depth of cut (DOC)



Boring		
Chip Breaking and Feed Marks		
Problem	Cause(s)	Solution(s)
Chip Breaking	Chips too short and/or hard 	Increase cutting speed, decrease feedrate
		Select a chip breaking insert (more open)
	Chips are too long 	Increase feedrate, decrease cutting speed
		Choose an insert with a more closed chip breaker
Feed marks 	Feedrate is too high	Choose a knife edge wiper insert
		Use an insert with a larger nose radius
		Decrease the feedrate

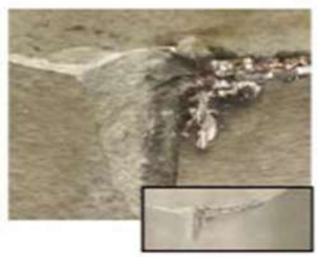
Boring

General

Problem	Cause(s)	Solution(s)
Insert Wear 	Wrong cutting data	Change cutting edge and inspect worn edge with Sandvik Tool Wear app or refer to Insert Wear Page in this guide
Chips scratching surface	Poor chip breaking	Refer to chip breaking on previous page
Surface finish 	Poor surface finish	Increase cutting speed, use coolant, use a cermet grade insert

Insert Wear		
General		
Problem	Cause(s)	Solution(s)
Flank wear	Insert material lost due to friction between insert and workpiece	Decrease cutting speed, increase feedrate, results in increased tool life
Crate wear	Occurs as a result of chips contacting the insert face	Decrease cutting speed, select insert with more wear resistant coating
Plastic deformation (depression and impression)	Cutting forces exceeding the inserts yield strength	Select insert with higher hot hardness, and better coating
Flaking	Insert is exposed to tensile stress, reulting coat flaking	Increase cutting speed, and selecting insert with thinner coating
Thermal cracking	Rapid fluctuations in temperature	Select a tougher grade of insert, coolant should be applied in large amounts
Notching	Chemical wear, adhesive wear, thermal wear. Can cause burrs and work hardening	Decrease the entering angle and/or change the depth of cut
Fracture	Cutting forces are larger the amount of force the tool can resist	Select proper cutting data and check setup stability
Built-up edge	Built up material on the cutting edge of the insert, causes increased cutting forces	Increase the cutting speed, and choose an insert with a sharper edge
Note: Please refer to the Sandvik Tool Wear app for an easier to use and more comprehensive guide on tool wear. For quick reference the next two pages contain examples of tool wear.		

Insert Wear	
Problem	**Picture**
Flank wear	
Crater wear (chemical)	
Plastic Deformation (depression and impression)	 Edge depression  Edge impression
Flaking	

Insert Wear	
Problem	**Picture**
Cracks (thermal)	
Chipping (mechanical)	
Notch Wear	
Fracture	
Built-up Edge	

IW 3

Turning

Parting and Grooving

Drilling

Boring

Insert Wear

APPENDIX B

Proposed Future State for Organization

Evan Charity, Michael Septon and Zachery MacNabb

Organization is one of the most common downfalls of the current state. We are proposing to implement systems that will improve and maintain the organization of the tools and tool room. The basis of our proposal is to clearly identify what tools are available and maintain a traceable system within the toolroom.

The drawers of the existing toolboxes will be divided into sections that are sized to fit one tool, there will be one section for each tool in the shop. The sections will be divided by drawer dividers and these dividers will be labeled with a tool identification number. This will make it clear what tool goes in what section. Inserts will not be included in this system because the vending machine provides a means for organizations.

The tool identification numbering system is an easy way to reference the tools, for example if somebody notices an empty section in a drawer the identification number can be used to determine what tool is supposed to be in that section. Also, if a tool is placed in the wrong section it will be obvious because the tool doesn't match the label. Since the tool identification number is used to locate the tool, it can be referenced on the setup sheet to tell the operator what tool they need and where to find it. A proposed numbering system is shown in figure 1, there is a 2-letter code that represents the type of tool, this is followed by the size of tool and an identification for the unit system. For example, a 2" drill would be labeled DR-2.000-I. This system is designed to be as simple as possible so it can be quickly referenced. There is also room for expanding the tool inventory because new tool types only need a new 2-letter code.

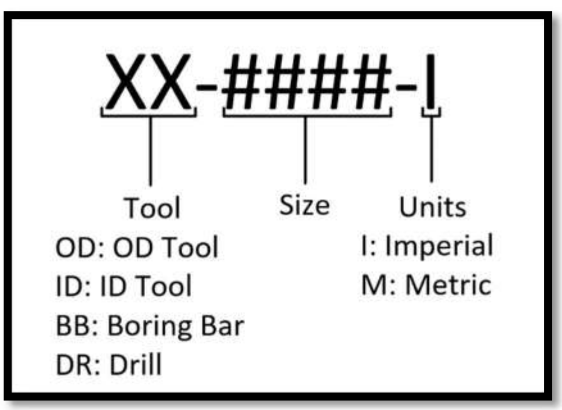


Figure 1: Tool Identification system

Laminated cards will be stored at each machine. The card will simply be an image of the character that corresponds to the machine, for example Bowser cards will be located at the Bowser machine. The cards will be used as a placeholder for the tool while the tool is in use. When an operator picks up the tool, they leave the laminated card in its place, then when the tool is returned, the laminated card can be retrieved. This means that a tool can be traced to the machine if it is not in the toolbox. If a tool is missing and there is no laminated card, it will be assumed that the tool is missing on the shop floor. This means operators can be notified of a missing tool and they can "keep an eye out" for it. The system provides some accountability to the operators, for example if there are four ½" boring bars at bowser, there will be 4 bowser cards in the toolbox, and it will be obvious that there is a mistake. This system is meant to minimize missing tools and make it obvious where the tools are being used. We wanted to implement this because when we were looking for tools, we weren't sure if they were all out on the shop floor, if they were missing or if they were in the drawer.

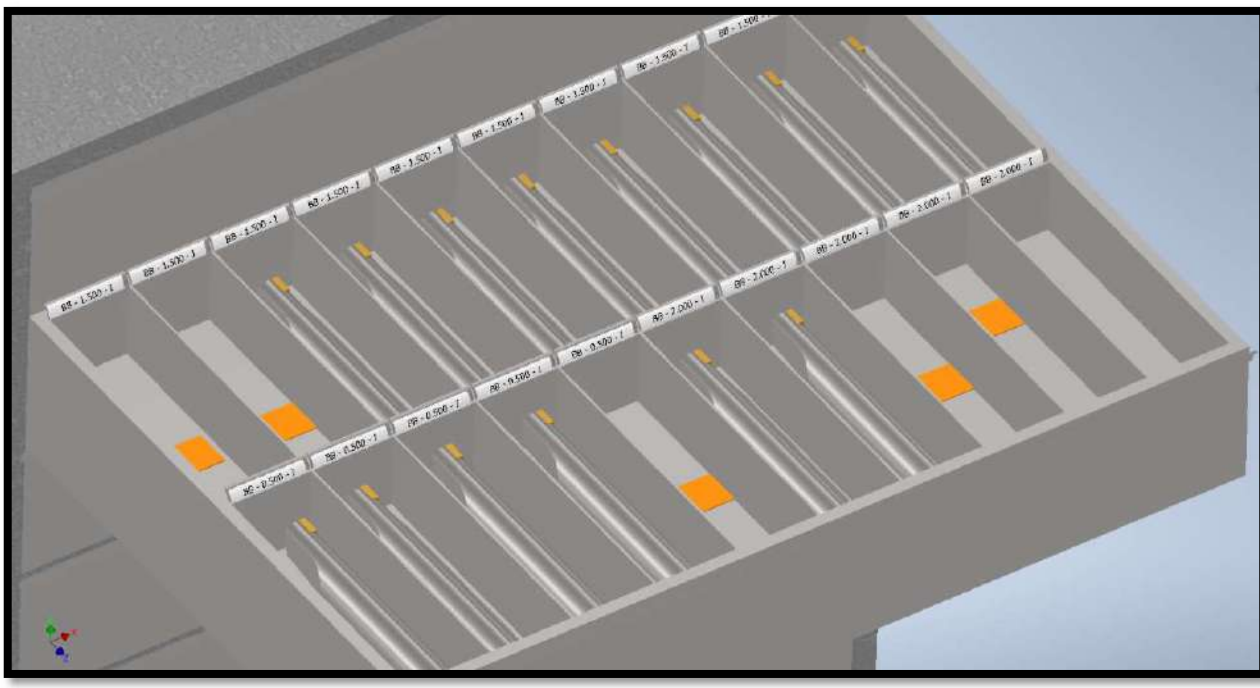


Figure 2: Example of a Toolbox Drawer

Figure 2 shows an example of how a drawer of boring bars could look. It is obvious that five boring bars are in use because the cards are left in place of the boring bar. It is also clear that the boring bar in the bottom right is unaccounted for because there is no card, and there is no boring bar. The label shows the tool identification number for a boring bar so it is clear that a boring bar is meant to be in that place.

One of the main objectives of our tool organization system is to make it immediately obvious if a tool is in use, missing or available for use. To achieve this, the toolboxes will be divided into sections by using drawer dividers. Each tool will have its own section, this section will be labeled with a tool identification number. When the tool is in use a laminated card will be used as a place holder. The combination of these systems will make it more obvious where the tools are and if any tools are missing. The proposed systems utilize the current toolboxes and toolroom so the system will be cost effective.

APPENDIX C

<u>Tool Room Organization Report</u>

Evan Charity, Michael Septon and Zachery MacNabb

Collet Holder

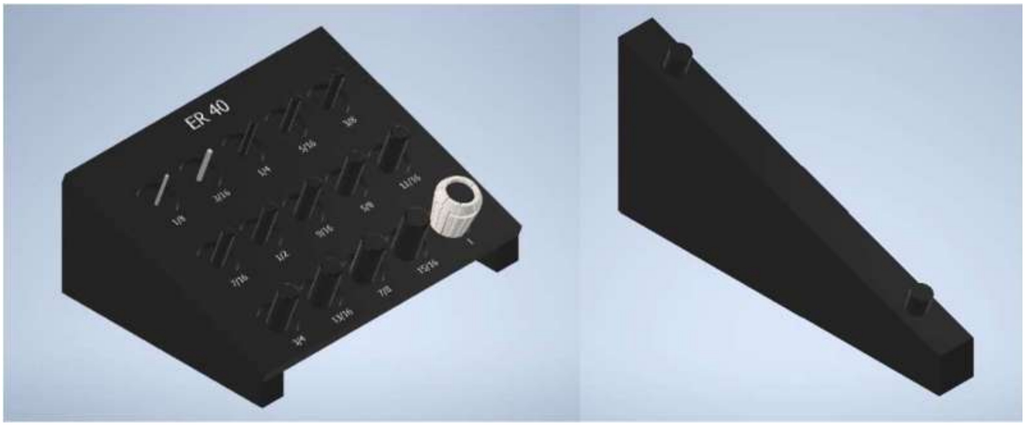


Figure 1: Collet Holder (left) and Side Panel (right)

The collet holder is built from three 3D printed panels that are assembled by force fit pins that are built into the side panels. Metal cylindrical pins are used for the ¼” and 3/16” collets because the pins would likely shear off if they were 3D printed, these pins will be press-fit into the faceplate of the collet holder. The faceplate can be printed with no supports while the side plates will need minimal supports under the pins.

Pins were used to locate the collets because this somewhat limits the amount of misplacement of the collets, for example a ¼” collet won’t fit onto the ¾” position because the ¾” pin is too large. There is still room for error with this system because a larger collet can fit in a smaller collets position, if the operator is unsure of the collet size, he should be instructed to try larger sizes first and work their way down until they find the proper size. The recesses on the faceplate of the collet ensures that the correct type of collet is being placed on the tool holder.

Allen Keys

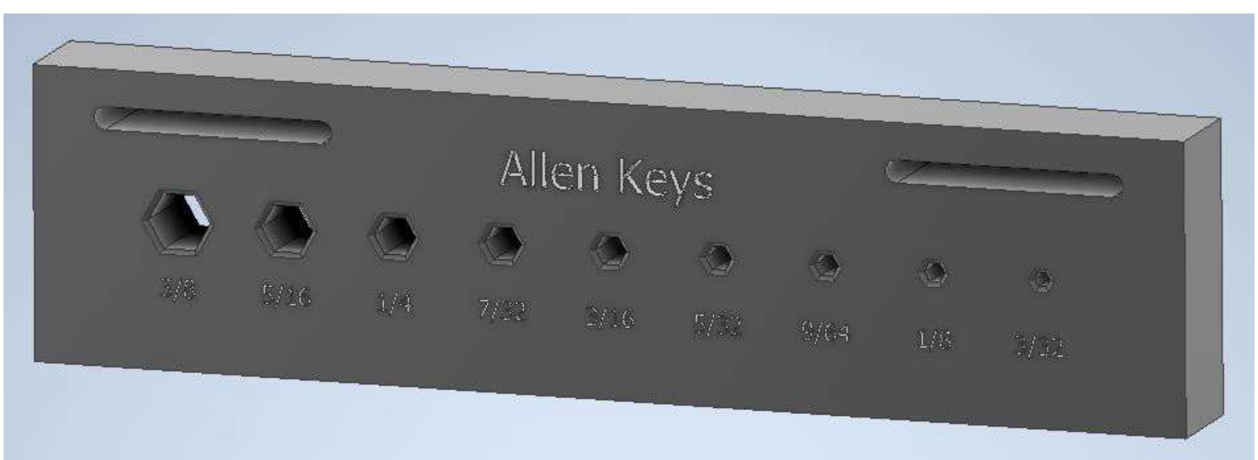


Figure 2: Allen Key Holder

The Allen keys will be positioned by putting the short arm of the Allen key into the hex shaped holes on the Allen key holder. The keys will hang off the side, this was chosen to prevent a smaller Allen key being put into a larger position. If this happens, the Allen key will either slide out or sit at an angle, so it is visually obvious that it is in the wrong place. The slots in the top corners of the Allen key holder are for hanging the tool holders using the pegboard hooks. The reason for using slots instead of holes is so the holder can fit on different pegboards without needing to be resized. The chamfers around the hex shaped holes make it easier to put the Allen keys into the holes.

Toolholder Organization

In figure 3 below you can see an overview of typically what the shelf should look like regarding the organization of the toolholders. Each toolholder will have a specific location on the shelf identified by a label in front of the location on the shelf where it belongs. Above each of the toolholders will be blue bins containing all the items necessary to assembly the toolholder in a machine.

Figure 3: Toolholder Shelf Overview

In figure 4 below you can see the items that 4 bins are to be assembled above each toolholder so that there is a designated place for each item that pertains to each toolholder, such as bolts, O-rings coolant plug and set screws. Every time a tool is placed back on the shelf it should be placed back in its designated location based on the label identified on the shelf and all pieces should be disassembled and cleaned before being placed in its rightful place inside each of the bins according to the labels on the bins. The bin sizes that were used to create the inventor files in this document are identified in figure 5 below. These are the recommended bins from Home Depot; however, they are not necessary if other means are more applicable or accessible. The link to the bins identified in figure 5 is https://www.homedepot.ca/product/husky-stackable-click-bins-in-grey-4-pack-/1000752010

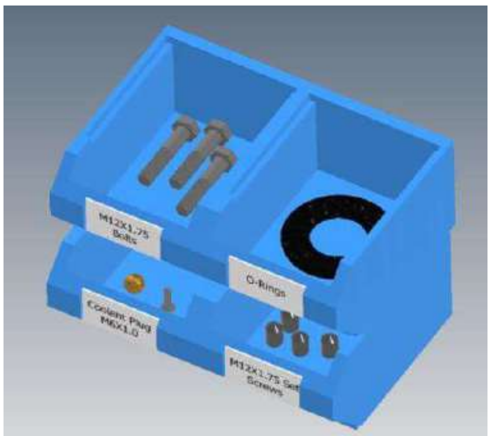


Figure 4: Bin Items and Labels

Figure 5: Recommended Bins from Home Depot

As seen in figure 6 below when a toolholder is missing from its location and all the parts are missing as well it can be traced back and located to the machine it is being used on by placing a card that identifies which machine the tool is located at. For example, in the picture below it shows a card as a placeholder for the toolholder that used to be there, this card identifies that the missing toolholder is located at the Wario Machine and can be traced back to that machine.

Figure 6: Empty Toolholder

There should be 4 bins above each toolholder as mentioned earlier, two sets of two bins should be stacked on top of each other side by side to conserve space. These bins can be located to the shelf using wood screws and two cradles to balance the load. The cradles will hold the bins while the screws will locate the cradles against the plywood shelf.

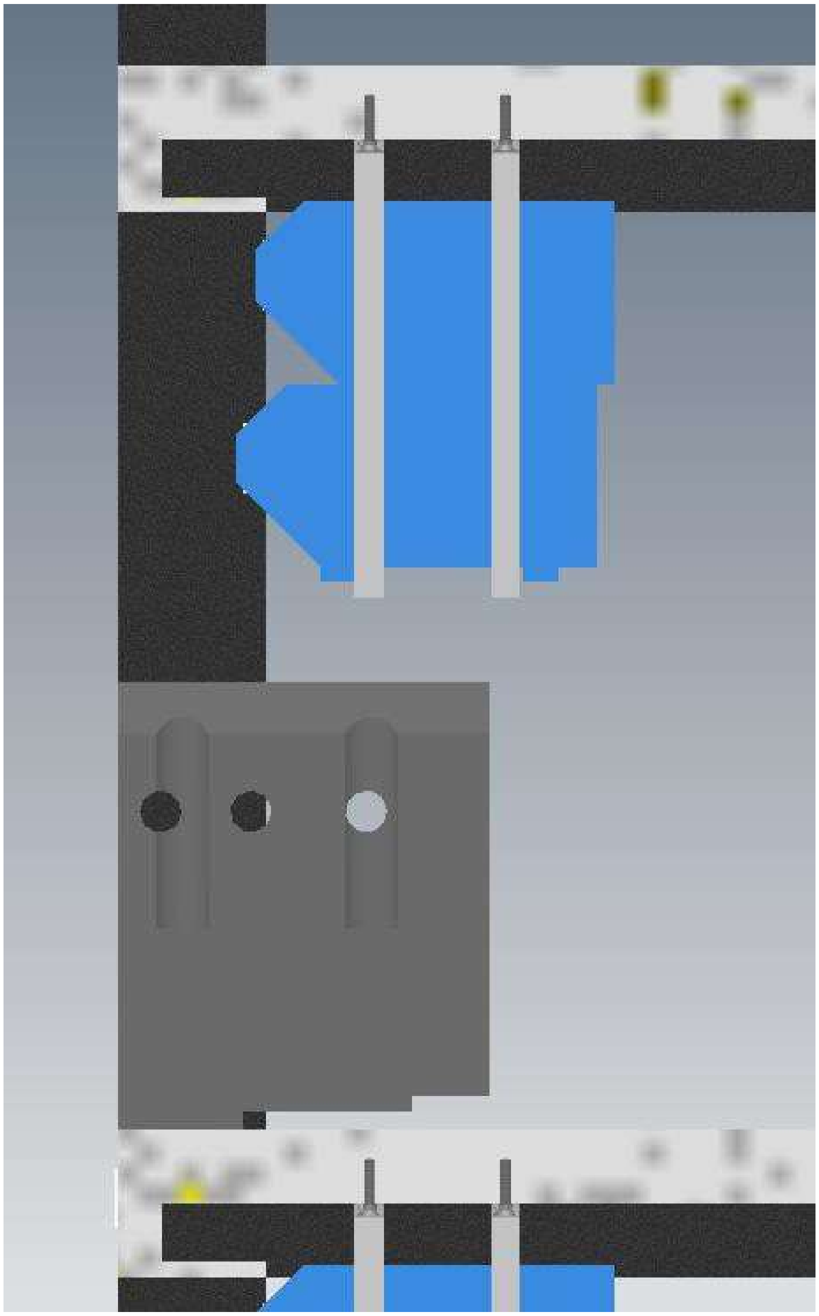


Figure 7: Bin Locating

As mentioned above these are the cradles that can be used to locate and support the bins above the tool holders. Two of these should be used per cradle set in order to support the bins properly. These cradles can be 3D printed if convenient or made by other means if the designer finds it necessary. A drawing has been provided for the cradle in figure 9, however these dimensions will probably need to be changed based on actual sizes and clearances available based on selected bins and shelf thickness.

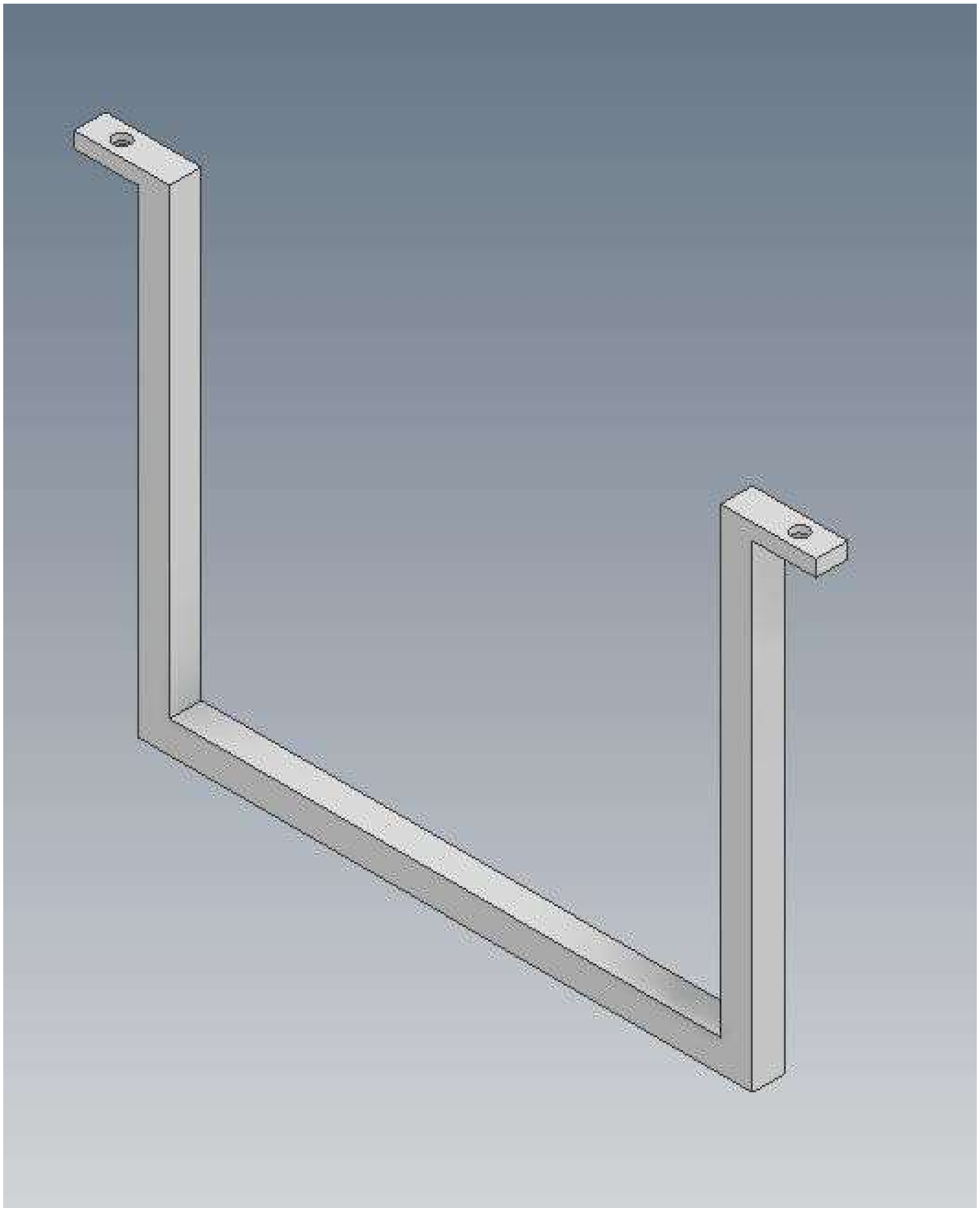


Figure 8: Cradle Model