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Using Ishikawa Method in Power Hacksaw Maintenance

Tsapi T. Kevin [1,*]; Nanah N. Grace[2]; G. F. Kuiate[3]; Beching R. Oru[4]
[1,2,3,4]Depatment of Mechanical and Industrial Engineering, National Higher Polytechnic Institute,
The University of Bamenda, Cameroon

Abstract:- Mechanical manufacturing companies engaged in mass production cannot do without the cutting of raw materials for the assembly of new machines. The overall objective of this research endeavor was to identify and subsequently correct of the underlying factors responsible for the malfunction of a power hacksaw machine that had been left unused at LAHMOTECH for several years, using the Ishikawa medthod. Within the framework of the research, sequences of steps were taken to in order to successfully and permanently address the problem. An initial diagnosis was performed, followed by the implementation of the Ishikawa method to identify the root causes of the failures. A corrective action plan was then developed. As a result of the methods performed, some of the root causes identified were operator neglect of maintenance, the absence of the cooling system, exposure of the motor, etc. Corrective actions implemented included replacing the blade, adaptation of a lubricating system, and cleaning of the motor, etc. The Ishikawa diagram provided the advantage of a correct orientation to correct the non-conformities. The performance rate of the power hacksaw machine after maintenance was 83%.

Keywords:- *Ishikawa Method; Power Hacksaw; Corrective Maintenance, Corrective Action Process.*

I. INTRODUCTION

Located in Bamenda, Cameroon LAHMOTECH is a fabrication company specializing in the maintenance and fabrication of agricultural machinery, woodworking equipment and the repair of heavy-duty vehicles. The company primarily uses handheld hacksaws for cutting operations, while angle grinders are used for thicker materials. While these tools are adequate work for most fabrication tasks, there is still room for improvement in terms of efficiency and productivity. While the hacksaw is easy to use, it has limitations when cutting large thicknesses and prolonged use of the hacksaw can lead to musculoskeletal disorders that reduce worker efficiency. Angle grinders, on the other hand, are suitable for cutting thicker materials, but they pose safety risks and are dependent on the operator for cutting accuracy. Inconsistent accuracy often results in material waste and longer production times, which affects customer satisfaction. Due to the limitations of the portable hacksaw and the angle grinder for mass production, the company decided to refurbish a retired power hacksaw (figure 1).

To rehabilitate the power hacksaw, it was imperative to have a detailed understanding of the various causes of the machine's unavailability. Typically, there is a mismatch between the expected benefits of maintenance strategies and the performance achieved. While practitioners may appear to be doing things right, with various maintenance activities in place to improve system reliability, the effectiveness is often questionable. Consequently, there is a need to uncover the issues that affect equipment failure when addressing maintenance pitfalls and to generate effective maintenance management action plans, thereby maximizing the achievable benefits [1].

Fig 1 Retired Power Hacksaw at LAHMOTECH

Ishikawa Method, also known as the Fishbone Diagram is a valuable tool for maintenance professionals seeking to address and prevent issues in a structured and systematic way that helps determine not only what and how an event occurred, but also why it happened. Only when investigators are able to determine why an event or failure occurred can they determine viable corrective actions to prevent future events of the type observed [2]. Understanding why an event occurred is key to developing effective recommendations for corrective and preventive actions.

Although there are many advanced cutting machines available worldwide, LAHMOTECH is not exposed to such opportunities and such technologies are quite expensive and sophisticated for a growing industry. However, due to the inadequacy of the tools used by the company [3, 4, 5, 6, 7], the overall objective of this research effort was to identify and subsequently correct the underlying factors responsible for the malfunction of a power hacksaw machine in order to optimize production.

II. RELATED STUDIES

Different cutting tools and machines are used by different manufacturing companies where mass production requires more and more number of round or square bar pieces to be cut and machined on different machines to produce machine components such as shafts, bolts, screws, etc.; nowadays, many electrically operated cutting machines from different companies with different specifications are available for use in shop floor [4, 8] including the power hacksaw, power band saw, circular saw, angle grinder and hand operated hacksaw.

While the importance of the hand hacksaw as a simple hand tool for cutting metals and non-metals cannot be overemphasized, the manual labor involved in its operation is very cumbersome and tiring when a large number of cuts need to be made on materials with thick and wide dimensions. This may have led to the idea of applying power to the principle of saws, which were originally designed to perform various cutting operations requiring the use of simple hand tools [5].

Power hacksaw, as the name implies, is a type of hacksaw that is powered by a low speed electric motor, which sometimes requires reduction from the normal motor speed to a moderately low speed that is suitable enough to drive the sawing machine parts [6]. The principle of operation of power hacksaw and band saw is to pass a blade with a series of teeth on its edge through a given workpiece to cut a narrow opening in the workpiece [5].

The power hacksaw shown in figure 2 is a machine used to cut across materials such as aluminum, brass, and mild steel. There are many electrically operated power hacksaws [7, 8] from different companies with different specifications available for shop floor use, such as utility, heavy duty, and high production models. Power hacksaws are widely used in operations that require cutting of large dimensional materials such as metals, wood, plastics, glass, etc. and they have been designed to perform the difficult and time consuming work in minimum time, but they have one and major disadvantage that those are able to cut one piece of bar at a time [4].

Fig 2 Hacksaw Machine [8]

A band saw (figure 3) is a power saw with a long, sharp blade that consists of a continuous band of toothed metal stretched between two or more wheels to cut material. They are primarily used in woodworking, metalworking, and lumbering, but can cut a wide variety of materials [9]. In recent years, the power band saw has become very important in machine shop operations.

Compared to the bandsaw, the power hacksaw is slower because it cuts into the material in a forward and backward motion, with the cut occurring only during the backward stroke. A horizontal bandsaw, on the other hand, works continuously without wasting a stroke. There is no question that the bandsaw is far more effective than the power hacksaw in terms of efficiency.

Fig 3 Horizontal Bandsaw Machine

The circular saw (figure 4), also known as a cold saw machine, is a power saw that uses a toothed or abrasive disk or blade to cut various materials using a rotary motion that rotates around an arbor. A metal cutting circular saw machine is designed to shear various metals at high speed with the toothed cold blade, allowing both the saw blade and the raw materials being cut to remain cool during the operation [10]. To achieve this, the saw blade transfers the heat generated to the metal chips formed during the high-speed metal cutting process. In the high-speed cold sawing process, the metal materials are released by the blade teeth in the cutting motion as the feed system rotates the saw forward toward the work pieces.

Fig 4 Horizontal Circular Saw

Circular saw blades are thicker and stiffer than band saw blades. This reduces vibration, which can dramatically reduce the efficiency and life of the blade and increase the overall cost per cut. While band saws are less expensive, circular saws offer higher productivity. The main disadvantage of the band saw is that it is more dangerous than other power saws such as the jigsaw or reciprocating saw.

In the past five years, as a contribution to research and development, few studies have been conducted on the power hacksaw machine. Using a step-down transformer to convert 220-230V AC power to 12V DC power, a motorized hacksaw machine was designed and manufactured [4]. An automatic cooling power hacksaw machine for multipurpose applications was designed in [5]. The machine took an average time of 40 s to cut an average mass of 5.9 kg with an average specific mechanical energy (SME) of 29 kj/kg and an average cutting speed of 270 rpm. In [11], a double-sided shaping machine was fabricated using a scotch yoke mechanism to demonstrate the reduction in machining time for double-sided shaping machines. This arrangement reduces the machining time of a workpiece by half. Another author developed a prototype model of a portable hacksaw machine using a crank and slider mechanism along with a linear bushing [12], which can be used in remote locations where electricity is regularly available.

In this context, the Ishikawa method of root cause analysis was applied to a retired power hacksaw system at LAHMOTECH in order to simplify the cutting process for the machine operators and to enable effective maintenance, thus saving time, energy and material waste.

III. MATERIALS AND METHODOLOGY

Materials

The materials used to perform corrective maintenance on the power hacksaw based on the Ishikawa method were tools (wrenches, screwdrivers, scribers, etc.), software (Microsoft Excel), and forms (diagnostic form, root cause analysis form, purchase form). The following materials were used for corrective maintenance: welding electrodes, water hoses, sheet metal, a pump, nuts and bolts, square mild steel pipes, etc.

Methodology

The root cause corrective action process is a valuable tool for maintenance professionals who want to address and prevent problems in a structured and systematic way. The flowchart in figure 5 has been developed and is used throughout the root cause corrective action process.

- *Build a Team:*

The Ishikawa method encourages cross-functional collaboration. Maintenance personnel, engineers, operators and the manager worked together to brainstorm and analyze problems to ensure a comprehensive description of the problem condition.

- *Problem Identification:*

The first step in solving any maintenance problem is to clearly define it. The teams identified potential problems through diagnosis, considering all aspects of maintenance.

- *Root Cause Analysis using the Ishikawa Method:*

The Ishikawa Method is a structured technique for identifying and analyzing the root causes of problems. The method uses a fishbone diagram to visually represent the causes and effects of a problem. The main categories or branches on the diagram include Man, Machine, Material, Method, Measurement and Mother Nature (the 6 M's).

- *Corrective and Preventive Actions:*

Once root causes were identified, the maintenance team developed effective solutions to reduce, prevent or eliminate the identified problems. These may include process improvements, equipment upgrades or changes in maintenance procedures. They focus on completely breaking the chain of cause by addressing the contributing causes and the root cause.

- *Monitoring and Evaluation:*

To ensure that the corrective actions that have been taken are effective.

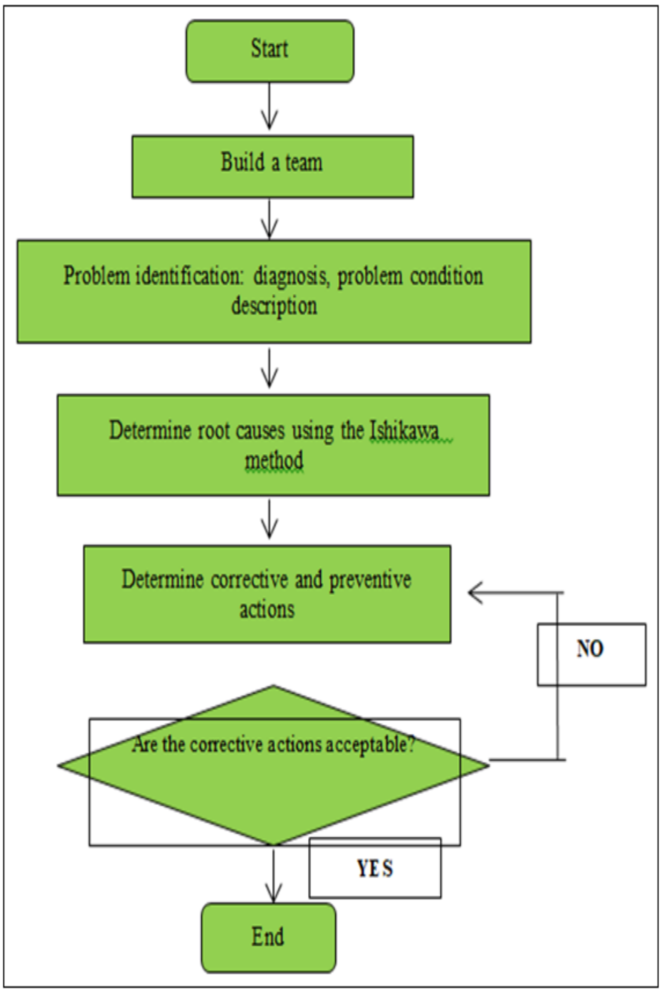

Fig 5 Methodology by Steps for Root Cause Analysis and Corrective Action

IV. RESULTS AND DISCUSION

A. Diagnosis, Problem Condition Description

After running diagnostics on the power hacksaw, the team was able to locate several components of the machine that were critical to the operation of the machine, but for some reason were not functioning. These components included the cooling system, the engagement system, the motor, the cutting unit, and the stand.

- *Cooling System*

The cooling system had been completely removed, and only a clip was available to show that there was in fact a cooling system in place.

- *Engagement System*

The engagement system consists of the dog clutch, clutch lever, and release lever. As shown in figure 6, there was a gap between the release lever and the clutch lever, and this gap made it impossible for the clutch lever to engage. It was also noted that the release lever had been repaired because it was broken. Since the machine could not be engaged for cutting, it could not be disengaged automatically.

Fig 6 Picture of the Clutch Lever and Trip Lever before Corrective Action

- *The Motor*

The motor was connected to a power supply but could not start. On opening it, a lot of dirt and iron fillings were discovered inside.

- *The Cutting Unit*

The cutting unit consists of the blade, bow and follower. It was observed that there was wear on some points of the blade (figure 7). And after using the blade for some time, the blade broke.

Fig 7 Worn out Blade

- *The Stand*

A pair of legs on the power hacksaw stand were broken and out of position as shown in figure 8 below. There were several cracks in the stand. The paint was peeling and dirt and rust had accumulated on the stand.

Fig 8 Picture of Broken Legs of the Power Hacksaw Stand

The diagnostics that were performed revealed faulty components of the machine. Some legs of the stand were broken and as a result the power hacksaw was no longer in a balanced position and cutting could not be performed due to the intense vibrations, which could lead to further cracks in the frame. The absence of the cooling system, which is a very critical part of the power hacksaw, meant that the blade of the power hacksaw would be damaged prematurely. Another component that failed was the dog clutch. The dog clutch consists of the clutch lever, the release lever and the shafts.

The release lever was found to be defective because there was a gap between it and the clutch lever, making it impossible to engage and disengage. This handicapped the machine as the cam and follower would not transfer motion to the blade. The blade was identified as another critical component; the teeth were worn, making it very inefficient in cutting material and also affecting the quality of the finished product. The motor was found to have so many iron fillings that it would not start, leaving no power source for the machine to function.

B. Root Cause Analalysis

From the cause and effect diagram of the broken stand shown in figure 9, we can see how each category contributed to the failure of the stand. The main causes are the non-malleable material used for the stand and the workers' carelessness with the machine; the machine was exposed to adverse weather conditions.

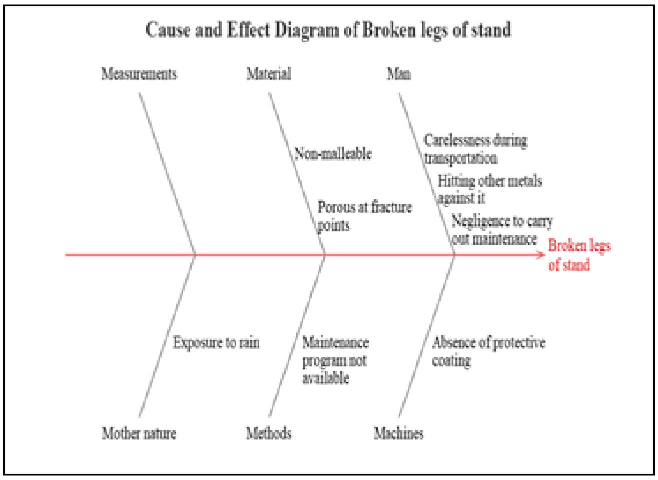

Fig 9 Cause and Effect Diagram of the Broken Stand

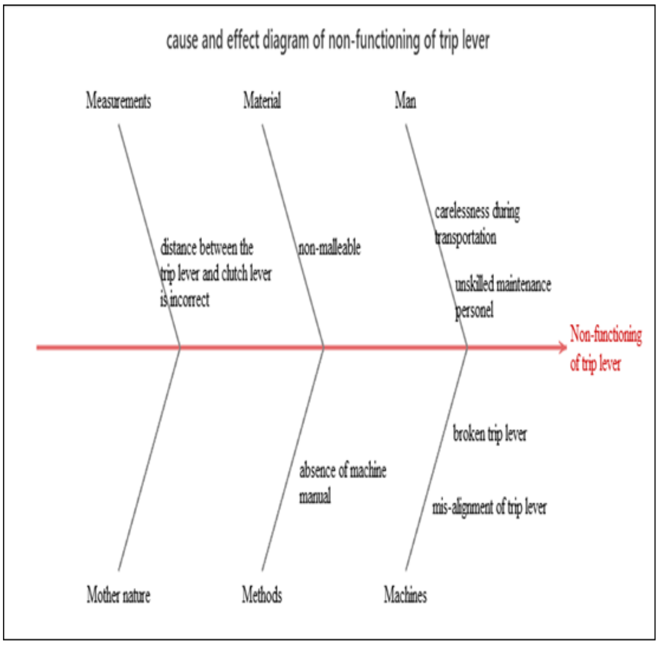

Fig 10 Cause and Effect Diagram of Non-Functioning Trip Lever

From the cause and effect diagram of the non-functioning trip lever in figure 10, it was observed that a mis-alignment of the trip lever, a distance between the trip lever and cluth lever. The maintenance which was carried out on the trip lever in the past did not take into consideration the role which the trip lever plays and as such, the root cause of this problem was the untrained maintenance personnel, absence of machine manual, etc.

From the cause and effect diagram for the lack of a cooling system, figure 11, we can summarize that the root causes of the problem were the inability of workers to perform preventive maintenance on the cooling system, water pipes that could not withstand high temperatures, and so on.

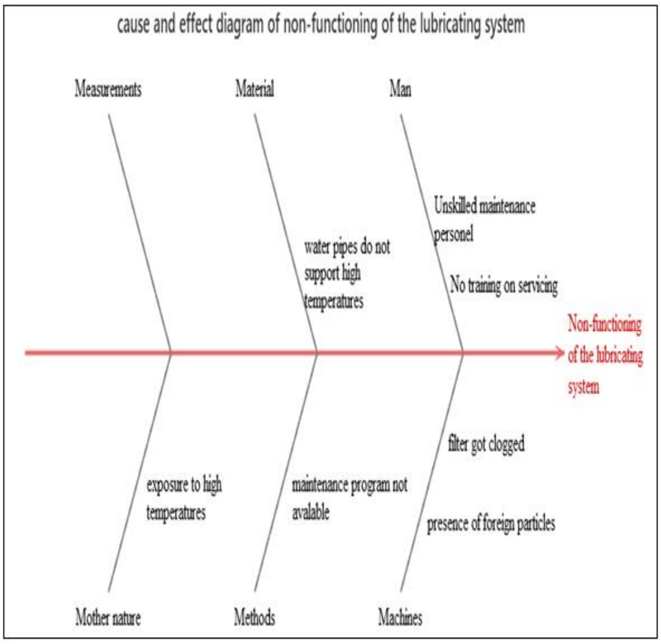

Fig 11: Cause and Effect Diagram of Removed Cooling System

From figure 12 of the Failure to start cause and effect diagram, the causes of this problem can be identified as not maintaining the engine and exposing it to adverse weather conditions with the presence of foreign particles.

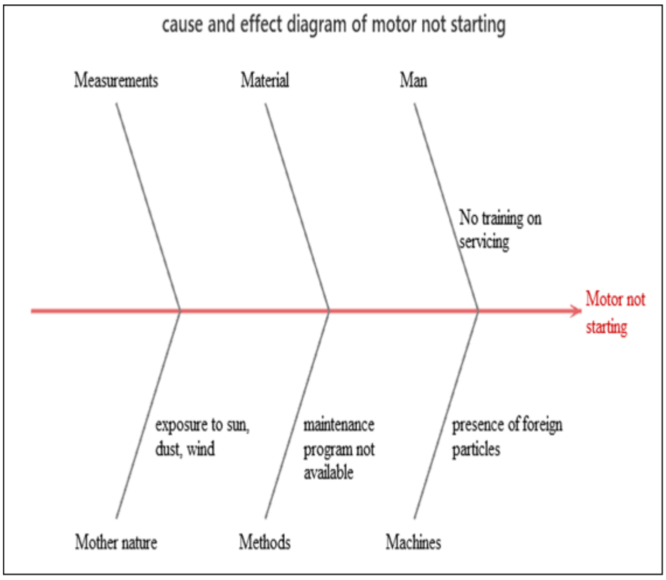

Fig 12 Cause and Effect Diagram of the Motor Failure

The absence of a lubrication system and the lack of operator training on blade care were the main causes of the worn blade (figure 13).

The absence of the cooling system is due to operator neglect. Operators did not understand that the life of the blade depended on the cooling system, so when the cooling system failed, they simply removed it and decided to cool the blade manually as needed. As a result, operators would sometimes stop operations for a few minutes to apply coolant to the blade, and this interruption typically resulted in downtime depending on the length of the interruption as reported in [5]. Effective cooling prevents chips from clogging the teeth, prevents breakage and excessive wear, increases blade life and, most importantly, saves time, energy and material waste [5, 13, 14].

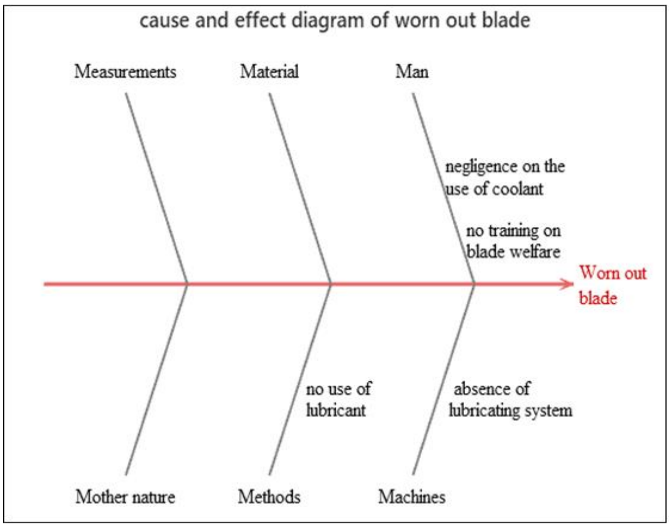

Fig 13 Cause and Effect Diagram of the Worn-Out Blade

From the diagnostics of the blade we can confirm that they did not cool off the blade manually either. The main reason why the motor could not start was due to its exposure to adverse conditions, adverse conditions here are the iron fillings from the angle grinders. The blade got worn out because of the absence of a cooling system, as we earlier discussed, the cooling system is very important for the health of the blade.

C. *Corrective actions*

- *Broken Legs of the Stand*

To repair the broken legs of the stand (figure 14), we realigned the legs to their right position using a G-clamp and secured them in place. One leg was secured with supports of mild steel sheets. The sheet was cut according to the area which needed support and bolted to the leg and welded such that in remains in position. The other leg was secured by simply welding it with steel electrodes.

Fig 14 Broken Leg after Corrective Maintenance

- *Cooling System*

The exact model of the pump could not be found, so we adapted a pump to the engine pulley and connected the water hoses to a tank (figure 15). The tank was made from the gas tank of a refrigerator. In case of lack of coolant, inadequate cooling, wrong coolant or wrong coolant supply, the heat generated during cutting may increase the blade temperature, reduce its mechanical strength and thus cause plastic deformation in the shear zone of the cutting blade and possible failures such as blade braking, curvilinear cutting, tooth braking, blunt effect etc. [14].

Fig 15 Pump and Tank of the Cooling System

- *Engagement System*

More material was added on the trip lever by welding it with steel electrodes and then it was shaped using a grinding disc such that the clutch lever could hook into it (figure 16). The trip lever was filled but at some point, the clutch lever kept on sliding off and disengaging and so we used the pin on the trip lever to hold the clutch lever in place and as such the system does not automatically disengages.

Fig 16 Trip Lever and Clutch Lever During Corrective Maintenance

- *The Motor*

The inside of the motor was thoroughly cleaned (figure 17). It was sufficient to power the machine.

Fig 17 Motor after Corrective Maintenance

- *The Blade*

A new A Bahco sandflex HSS bi-metal saw blade (figure 18) was purchased and installed on the machine. The blade was selected based on the thickness of the material to be cut with special attention to the blade shape, tooth spacing and clearance [15, 16]. There are four types of blades based on the materials, namely high carbon steel, alloy steel, bimetallic strip and high speed steel blades. Among these four, the most suitable for cutting hard materials such as mild steel bar and aluminum is a bimetallic blade based on the material properties, wear resistance and cutting performance [7].

Fig 18 Brand New Saw Blade

Fig 19 Power Hacksaw after Implementing Corrective Actions

Corrective action was taken and the legs of the stand were properly positioned and we experienced less vibration. The trigger lever was filled, but we still experienced slippage during cutting. To overcome this problem, the trigger lever was moved to the engagement position and we use a switch to turn the power on and off. The cooling system was installed by adapting a new pipe that provides a flow rate of 1.1 gpm, which flows like an average kitchen faucet and will ensure that the blade is cooled quickly to preserve its life.

D. Monitoring and Evaluation

After the corrective maintenance was carried out, the performance of the repaired machine was tested using the principle of six major losses (figure 19). This experiment was carried out for six days, and the shift period was taken as the period of cutting 5 square steel bars. Table 1 below shows the activities carried out each day and the losses recorded within the day.

The performance rate accounts for when the process is running slower than its theoretical top speed. The performance rate of the equipment can be defined as;

$$Performance\ rate = \frac{Ideal\ cycle\ time \times Output\ per\ shift}{Operating\ time\ per\ shift}$$

The performance of the machine, which indicates how fast the machine works during production, is over 80% (Table 2), indicating the need for continuous improvement such as increasing the cutting speed of the blade.

Table 1 Table of Activities and Losses within the Days

Days	Activity	Loss	Frequency	Total loss (mins)
1	Cutting	Idling and minor losses	4	3.1
	Power failure	Idling and minor losses	1	2
2	Cutting	Idling and minor looses	4	3.3
	Belt at second reduction position	Reduced speed	1	3.5
3	Cutting	Idling and minor stoppage losses	4	3.3
4	Cutting	Idling and minor loses	4	3.2
	Power failure	Idling and minor stoppage losses	1	2.1
5	Cutting	Idling and minor stoppage losses	4	3.2
6	Cutting	Idling and minor stoppage losses	4	3.3

Table 2 Performance Calculation of Power Hacksaw

Operating time per shift	20.9	21.8	21	20	21.8	21.8
Output per shift	5	5	5	5	5	5
Ideal cycle time	3.5	3.5	3.5	3.5	3.5	3.5
Performance rate	0.84	0.80	0.83	0.88	0.80	0.80
Average performance	0.83					

V. CONCLUSION

Using the Ishikawa Method to identify and correct the root causes of the power hacksaw failure proved to be a valuable tool for maintenance professionals seeking to address and prevent problems in a structured and systematic way. By visually mapping out potential causes and effects, the team was able to identify root causes, make informed decisions, and implement corrective and preventive actions on the power hacksaw. For future studies, the overall equipment efficiency (OEE) of the power hacksaw, the modernity level of the machine, and the occupational safety assessment of the power hacksaw can be used to evaluate the level of machine operating effectiveness, the level of occupational safety of the maintained machines and the technological up-to-dateness of the machine’s subassemblies.

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