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Research Article
Application of Why-why Analysis to Improve Predictive Maintenance Strategy for Injection Molding Machine

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Abstract
Why-why analysis is known as a quality control tool to inquire the root cause of a problem. In this study "5-why" analysis is referring to Toyota Production System (TPS) and being used to improve the predictive maintenance strategy in a molding company. The "5-why" analysis is effectively used in factories adopted TPS, for a machine dependent company every minute of unplanned machine stops during production run is a cost and time lost. This study was focus on application and methodology for predictive maintenance base on the "Mean time to failure statistic" to reduce the number of production loses due to machine break-down. The "5-why" analysis method is used in order to know the machine condition and main issues. With the purpose to apply the "5-why" in predictive maintenance strategy at injection molding machine this study was performed as a case study.

Key words: Tool and die, mould, 5-Why, predictive maintenance, manufacturing industry

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Technological development resulted in increased complexity in both industrial machinery and production systems. The modern industry is constantly demanding for work at high reliability, low environmental risks and human safety while operating their processes at maximum yield. Therefore, prevention of failures and early detection of incipient machine and systems problems increase the useful operating life of manufacturing plant.

The competitive pressure on the market is forcing companies to explore every possible competitive advantage with the goal to find the potential in every single process. A high performing production system is not only dependent on an operational design but also on the processes of taking care of the system. This includes maintenance that aims to keep the system in an operational condition or bring it back to an operational condition after a break down.

Blending the "5-why" analysis with predictive maintenance this study produced a method of questioning that leads to the identification of the root causes of a problem. A why-why is conducted to identify solutions to a problem that address its root causes. Rather than taking actions that are merely Band-Aids, a why-why helps to identify how to prevent the issue from happening again. The root cause guides us to establish measures to protect organizations including the project from the same problems in the future[1].

There are six categories of maintenance such as perfective, corrective, preventive, predictive, prevention and adaptive. As much as one third of the maintenance cost is estimated to exist due to bad planning, badly performed preventive maintenance and overtime costs which lead to unnecessary increased production costs. With a correct maintenance strategy the downtime and the maintenance cost can be radically decreased. Until recently, middle and corporate level management have ignored the impact of the maintenance operation on product quality, production costs and more important, on bottom-line profit.

In this study, the predictive maintenance was selected and embedded with "5-why" anlaysis to encounter the problem occur in the injection moulding machine. To understand a predictive maintenance management program, traditional management techniques should first be considered. Industrial and process plants typically employ two types of maintenance management which is run-to- failure or predictive maintenance[2].

Run-to-failure management is the logic of run-to-failure management is simple and straightforward. When a machine breaks down, fix it and "If it ain't broke, don't fix it". A plant using run-to-failure management does not spend any money on maintenance until a machine or system fails to operate. However, it is actually a "No maintenance" approach of management. It is also the most expensive method of maintenance management[1].

Predictive maintenance is that regular monitoring of the actual mechanical condition, operating efficiency and other indicators of the operating condition of machine-trains and process systems will provide the data required to ensure the maximum interval between repairs and minimize the number and cost of unscheduled outages created by machine-train failures.

Predictive maintenance is much more, however. It is the means of improving productivity, product quality and overall effectiveness of manufacturing and production plants through a unique data set that assists the maintenance in determining the actual need for maintenance.

MATERIALS AND METHODS

In this study various types of diagrams such as cause and effect diagram, Pareto chart being used with the "5-why" analysis to help in identified and narrow down the finding. Two important cause and effect diagrams are:

- **cause listing diagram:** A listing of the possible causes of a problem. In the cause listing diagram, the problem is put at the far right side of the page as shown in Fig. 1. The diagram shown list a number of possible causes for voids in a product. A brainstorming session is a good way to come up with a large number of possible causes[3]
- **Variation analysis diagram:** A diagram used to analyse cause of variability in a process. The main conditions affecting the process are listed: Man, method, machine, material and measurement. Next, all the details that can contribute to the variability are listed under the main categories. An example is shown in Fig. 2, which list possible causes for dimensional variation in an injection moulded product[3]

The "5-why" analysis is a method of questioning that leads to the identification of the root causes of a problem. A "5-why" is conducted to identify solutions to a problem that address its root causes. Rather than taking actions that are merely band-aids, a why-why helps you identify how to really prevent the issue from happening again.

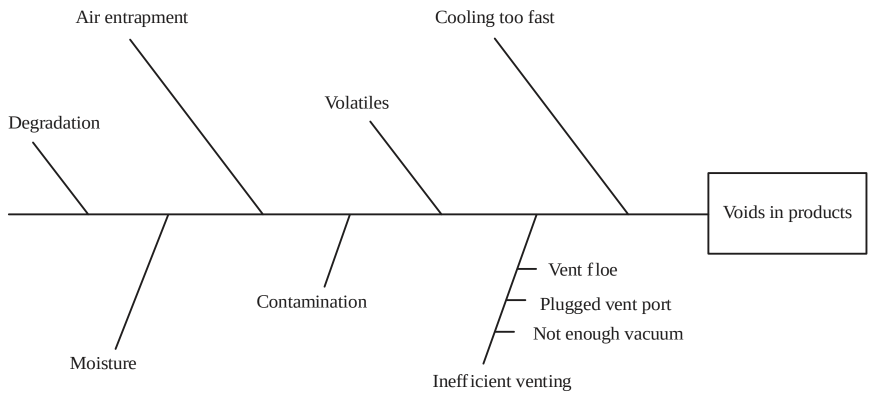

Fig. 1: Cause listing diagram

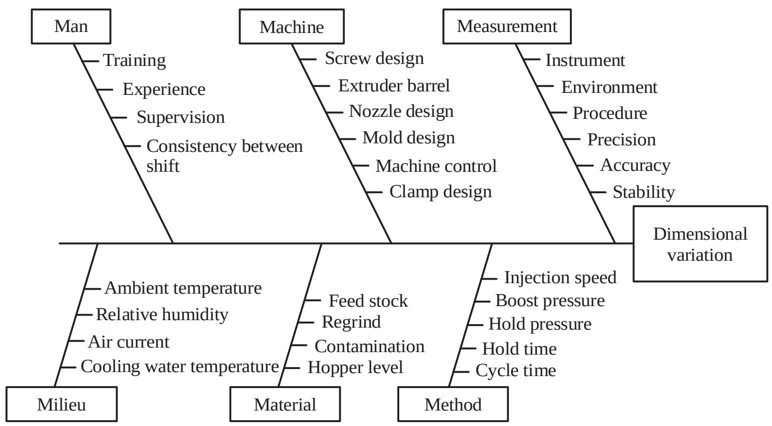

Fig. 2: Variation listing diagram

The “5-why” analysis in TPS is a methodology to inquire the root cause behind surface causes of a problem. The root cause guides us to establish measures to protect organizations including the project from the same problems in the future[1] as:

- After anyone asks “Why” 5 times, the person can get the root cause. Only experts can do it
- Everyone traces back the standards process with “Why”. The root cause doesn’t exist in only the beginning process

RESULTS AND DISCUSSION

The method of “5-why” analysis has been used to find out the main possibility that contribute towards machine become overheat (Table 1). From both of the problem findings method, the analysis and counter measure was made by using the predictive maintenance strategy in order to get the actual result[4]. The impact from the machine problem was affected the number of production loss, thus analyzing of the number of production loss also has been shown through a trend chart, histogram and pie chart.

Figure 3 shows the types of machine shutdown occur on the injection moulding machine. Based on the result, the overheat problem give the high impact of time that influence towards machine shut down which is 2690 min loss in 3 month compared to the others. The second high impacts that contribute towards machine shut down are changing the product which is 720 min loss in 3 month. Changing the product means the producing of the new part after the previous parts are completed to produce and it include the changing of the new mould.

The third type of machine shut down are minor maintenance which is 480 min loss in 3 month and this type of machine shut down are done because of following the preventive maintenance schedule weekly. Product defect was the last types that contribute towards machine shut down which is losses of 230 min in 3 month. This type is rarely happen because the number of product defect is low and if the defect occurs, the operator will counter the problem at that moment.

Figure 4 shows the Ishikawa diagram of injection moulding machine at company A. Based on Fig. 4, there

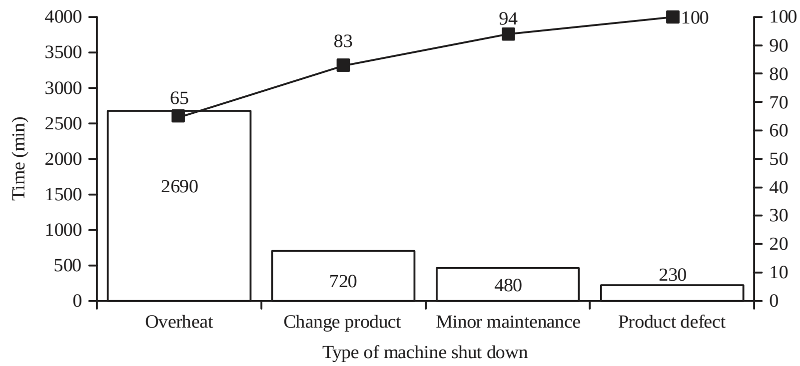

Fig. 3: Types of machine shutdown

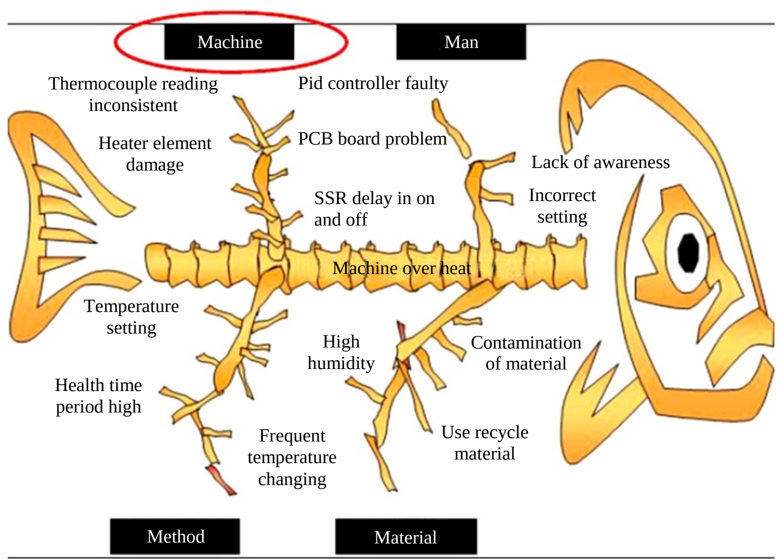

Fig. 4: Ishikawa diagram for machine overheat

Table 1: Why-why analysis[1]

What is the problem	Why 1	Why 2	Why 3	Why 4	Why 5	Verify true cause	Counter measure/remarks
Material drying	Lack of awareness	Operator overlook	New operator	-	-	False	Only experience and skills materials handler to set the temp
Material NCONSIS tant	Wrong setting	Lack of comprehension in training	No evaluation after training	-	-	False	Evaluation training provided by 4 months

are four causes that contribute to the machine become overheating which is machine, man, material and method. Each of these elements needs to be check and analyze deeply in order to know the main causes that influence of this problem[5].

For example in machine element, the component that are related to the process cycle in heater band need to be analyze in details to get the actual result for which component have a higher possibility to give an effect to the machine overheat. The same strategy will be used in man, material and method element in order to find out the main causes.

Table 2-5 shows the "5-why" analysis of injection moulding machine at company A. Based on the result obtain in the "5-why" analysis, it shows that the main problem comes from the machine rather than others element. The production stop because of the temperature reading in a heater band is out of the range from the actual temperature setup in Proportional Integral Derivative (PID) controller[6]. In that case, the machine become overheats and to counter this problem, future action need to be plan.

The basic process of injection moulding machine begin with the material or pallet are place in a hopper, then the

Table 2: Why analysis on men

What is the problem	Why 1	Why 2	Why 3	Why 4	Why 5	Verify true cause	Counter measure/remarks
Machine overheat	Lack of awareness	Operator overlook	New operator	-	-	False	Only experience and skills materials handler to set the temp
	Wrong setting in training	Lack of comprehension after training	No evaluation	-	-	False	Employee cannot by release to control the machine unless they pass during training

Table 3: Why analysis on material

What is the problem	Why 1	Why 2	Why 3	Why 4	Why 5	Verify true cause	Counter measure/remarks
Machine overheat	High humidity	Operator overlook	New operator	-	-	False	Only experience and skills operator are allow to set the temperature

Table 4: Why analysis on machine

What is the problem	Why 1	Why 2	Why 3	Why 4	Why 5	Verify true cause	Counter measure/remarks
Machine overheat	Heater element damage	Operator heating	SSR electronic switch components overheating	-	-	False	Replace with new heater element and SSR but still machine overheat
	Thermocouple reading inconsistent	Incorrect reading detected by the thermocouple	Internal short circuit in the thermocouple	-	-	True	Replace with new thermocouple but still machine overheat
	SSR delay in on and off	Delay on off signal coming from PID controller	Internal PID setting computation not in sync with heater	PID controller faulty	-	True -	Replace new PID controller but still machine overheat
	PCB board fail to functional	Incorrect reading send by PCB board to thermocouple	Fause burnt in PCB board	-	-	True	Replace with new PCB board. OK

Table 5: Why analysis on method

What is the problem	Why 1	Why 2	Why 3	Why 4	Why 5	Verify true cause	Counter measure/remarks
Machine overheat	Wrong temperature setting	Temperature setting is not based on material requirement spec	Controller only shows actual temperature at main display	-	-	False	Every material have a specific different temperature reading
	Frequent temperature changing	Improper changing temperature procedure	Temperature changing not follow the desired actual temperature	-	-	False	All the changing in temperature is based on the standard procedure

screw in a heater barrel will functional to drive the material and at the same time the material will melt in a heater band. When the materials are heated at a certain temperature then it will be injected into a mould and after a certain period of cooling time, the product is form[6].

Based on the Table 3, the main problem was detected on the heater barrel. Heater barrel is functional to heat the material at a preset temperature and the machine overheat problem was occur because of the temperature reading in heater barrel is over limit from the actual preset temperature[6]. The counter measure on the heater barrel should be taken in order to maintain the productivity.

Figure 5 shown that the number of production loss for three month after counter measure was made at the injection machine. The numbers of production loss are due to the machine shutdown and it is due to the same reason cause by overheating, mould change, setting part and minor maintenance during the production. Based on the result obtained, after changing the "Heater element" on

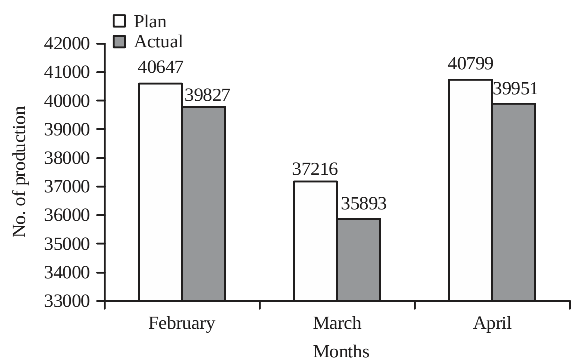

Fig. 5: Production loss at company A from February-April

February, 2014, the production team loss their product for 820 parts and on March, they still lost about 1323 parts after changing the "Thermocouple". It shows that the increasing number of production loss occur after changing the thermocouple. Then, the changing of Solid State Relay (SSR) on April, 2014 shows the production loss still occur whereas,

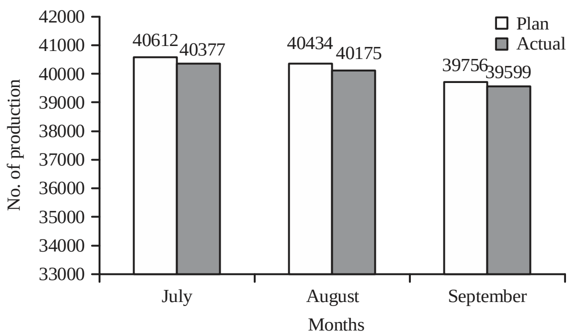

Fig. 6: Production loss at company A from July-September

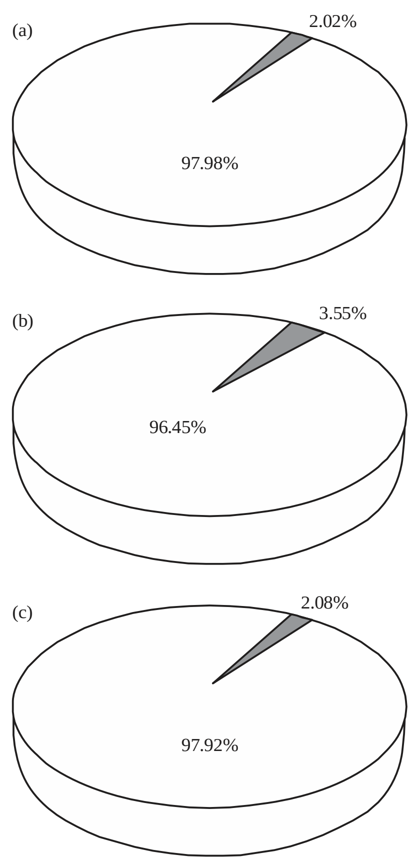

Fig. 7(a-c): Percentage of production loss (February-April)

they loss about 848 parts. This counter measure can be assumed as not successful and the next countermeasure should be taken.

Based on the result obtained on Fig. 6, the machine overheat problem has been encountered by changing a new PCB board on the injection moulding machine. The result shown that on July, August and September, the number of production loss is 235 parts, 259 parts and 157 parts. It shows that on this 3 month, the number of production loss was decrease to below 300 parts of losses compared to the previous result on February until April which is above 800 parts of losses. The changing of new PCB board gives the high impact towards the machine problem whereas at the same time it reduces a large number of production losses that due to the overheating problem.

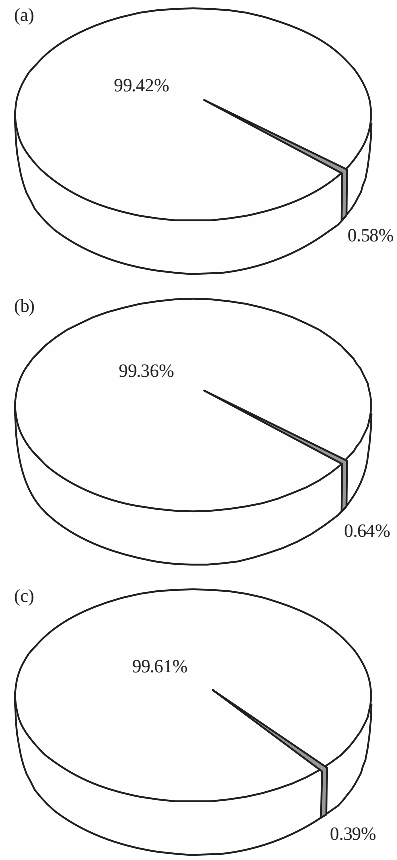

Fig. 8(a-c): Percentage of production loss (July-September)

Based on Fig. 7, result shows the percentage of production loss before counter measure of overheating problem. From the result obtained, the percentage number of product produce on February, March and April 2014 are 97.98, 96.45 and 97.92%. Instead, the total production loss occurs on these three months are 2.02, 3.55 and 2.08%. It shows that on every month, the production facing with the same problem and the existing of production loss even in a small scale, it can totally affect the company profit.

Figure 8 shows the percentage of production loss after counter measure of overheating problem was done. Based on the result obtained, after counter measure of overheating problem the percentage number of production loss on July, August and September, 2014 was decreasing to 0.58, 0.64 and 0.39% compared to the 3 month previous. It shows that overheating problem occur on machine give a high impact towards the production.

Most of the large company, production line is the most important department that can give a profit for company. Unpredictable machine shut down occur during the production run is the most worst situation whereas, the production need to be stop due to the machine failure[7].

Injection moulding machine is one of the machine that has been used in company A and this machine are facing with the serious machine shut down problem during the production. As mentioned above, due to this it will affect the machine condition and production as well. From the observation, the application of predictive maintenance[7] strategy will use on this machine in order to analyze where the problem comes from and the further counter measure will be taken. By implementation of pareto chart, ishikawa diagram and "5-why" analysis methods, the overheating problem was detected. Overheating problem can be detected through the heating process cycle between the main four components which is SSR, heater element, Thermocouple and PCB board. Further analysis towards this 4 component should be done in order to get a solution for the machine problem. From the analysis, the result showed after changing the new PCB board, the overheating problem was encountered and at the same time the number of production loss also decrease from the previous. The objective of this study has been successfully achieved whereas the number of production loss due to overheat problem was reduced by 79% which is more than the expected by using "5-why" analysis.

CONCLUSION

From the data that has been gathered, analysis and counter measure can be done to maintain the machine health. By using this method also, it has a high potential to detect problems that will be missed using the other predictive maintenance technique. Routine visual inspection towards machine itself will augment the other techniques and ensure that potential problems are detected before serious damage can occur. In production line, machine can be defined as the backbone of the production because it is the main process that can generate profit or loss for company. The experience and knowledgeable PIC is important in order to understand the machine behavior and can solve the machine problem in a short time. Unpredictable machine breakdown during production is a normal situation in a production line. A better analyzing from the PIC towards machine health can give a better result for machine condition in order to maintain the production even it has been use for a many years.

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