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Develop Total Productive Maintenance Checklists using Functional Based Approach

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Abstract

Total Productive Maintenance (TPM) is the most popular maintenance method in manufacturing industry. There are 8 TPM pillars, two of them are performing autonomous maintenance (AM) and preventive maintenance (PM) with specific guidance, which is called TPM Checklists. For well-established technology, the checklists are provided by machine vendor, and the users only need to follow them. However, for customized technology, users need to create the checklists by themselves. This situation requires specific guidance how to develop it. This research studies how to develop TPM checklist using functional based approach. Research was conducted by making TPM checklists for disc milling machine, then the developed checklists were validated to the existing TPM checklist built by the previous researchers. Results showed that the accuracy level reached 91.67%. It means that functional based approach can be an alternative solution to create and develop TPM checklists.

Keywords: *Total Productive Maintenance (TPM), TPM Checklist, Functional Based Design, Customized Technology, Disc Milling Machine*

Abstrak

Total Productive Maintenance (TPM) adalah metode pemeliharaan yang paling banyak diterapkan di industri manufaktur. TPM memiliki 8 pilar utama, diantaranya adalah melaksanakan kegiatan pemeliharaan mandiri dan pemeliharaan terjadwal dengan panduan yang sudah dibakukan, yang disebut *TPM checklist*. Untuk teknologi siap pakai, *TPM checklist* disediakan oleh pembuat machine, sehingga para pengguna mesin hanya perlu untuk mengikutinya. Tetapi, untuk mesin yang dikembangkan secara mandiri, pengguna perlu membuat *TPM checklist* secara mandiri. Penelitian ini mempelajarai bagaimana membuat *TPM checklist* dengan pendekatan fungsi produk. Penelitian dilakukan dengan membuat TPM checklist untuk mesin disk milling. Untuk memvalidasi tingkat akurasi dari metode pendekatan fungsi produk, *TPM checklist* yang sudah dibuat akan dibandingkan dengan *TPM checklist* mesin disk milling yang telah dibuat oleh peneliti sebelumnya. Hasil perbandingan menunjukkan bahwa tingkat akurasi mencapai 91.67%. Hal ini mengindikasikan bahwa metode pendekatan fungsi produk bisa dijadikan alternatif solusi dalam membuat dan mengembangkan TPM checklists.

Kata-kata kunci: *Total Productive Maintenance (TPM), TPM Checklist,* Fungsi Produk, Teknologi khusus, Mesin disk miling

1. Introduction

Indonesia as the fourth biggest population in the world becomes one of the top destination for manufacturing industry, it played important role to the Indonesia economic development [1]. To increase the economic rate from manufacturing industry, implementation of industry 4.0 need to be aligned with company business milestone [2]. To implement industry 4.0, some necessary technologies are required to be deployed properly. One of the biggest challenge in technology deployment is choosing adequate maintenance method to maintain the availability of the asset [3].

There are three types of maintenance which are commonly used in industry, Corrective Maintenance (CM), Preventive Maintenance (PM), and Predictive Maintenance (PdM). CM is only performed when the machine has problem, while PM is conducted regularly following the established schedule whether there is a machine problem or not. PdM is only executed when it is necessary, however it requires expensive sensors and other special equipment to be implemented. [4]

Currently, maintenance activities are not only defined as fixing broken machines, but also developing the habits and cultures for every individual worker in an organization. One of the most popular maintenance method that implemented in manufacturing industry is Total Productive Maintenance (TPM). TPM is defined as a method of physical asset management, focused on maintaining and improving manufacturing machinery in order to reduce the operating cost of an organization. TPM involves all workers, includes the operator to maintain their own equipment [5]. TPM has 8 pillars with 5S and lean manufacturing as baseline, as show in Figure 1 [6].

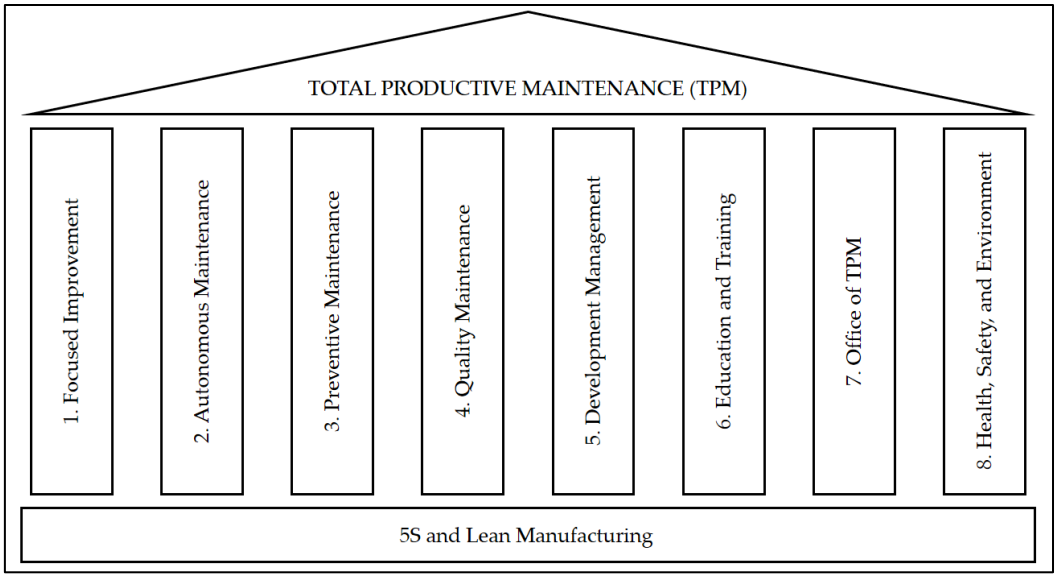

Figure 1. Total Productive Maintenance (TPM) pillar

There are two pillars which are related directly to machine maintenance, they are Autonomous Maintenance (AM), and Preventive Maintenance (PM). The main activities for those two pillars are performing specific activities to maintain the equipment in order to increase the machine availability [7].

Adequate AM and PM can increase the machine availability and eliminate asset loss [8]. AM and PM checklists are provided by machine maker for established technology. For customized technology, company needs to develop AM/PM checklists for maintaining the equipment properly.

Many industries build AM/PM checklists excessively, while some of them has lack of AM/PM checklists [9]. This research aims to present the method how to develop AM and PM checklists properly, not too much or not too less, in order to optimize machine utilization. For study case, this research develops TPM checklist for Disc Milling machine using functional based approach. To validate the results, developed TPM checklists will be compared to maintenance checklists developed by previous researchers.

2. Method

To develop adequate AM/PM, functional based approach is used as a tool to define TPM checklists. Functional based refers to one of the product design methodology, where functioning of the product is characterized by a verb-object (function-flow). Verb describes the mechanical function that represents the mechanism of the products **[10].** Functional based is described in the form of black box which is filled by the verb that represent the mechanism of the product and related parts **[11]. Figure 2** illustrates the example of functional based diagram approach of the cutter nails. Thick line refers to tangible external sources (hand, finger, etc), while thin line represents intangible parameters (force, energy, etc).

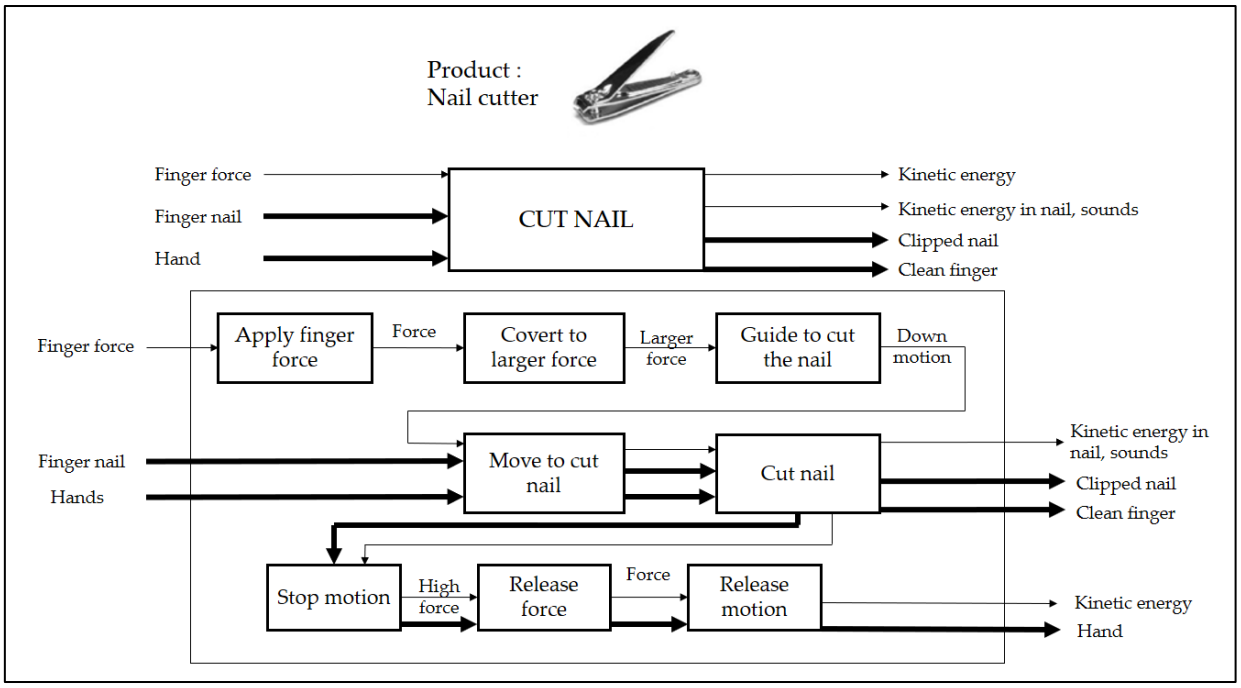

Figure 2. Functional based diagram of nail cutter

This research comprises five activities; create the functional product diagram of the disc milling machines, recognize the mechanism of the machine, identify the related spare parts, and define TPM checklists using line connection. At the end of the research, established TPM checklists will be compared

to the existing TPM checklists built by previous researcher. **Figure 3** shows the flowcharts of research sequences.

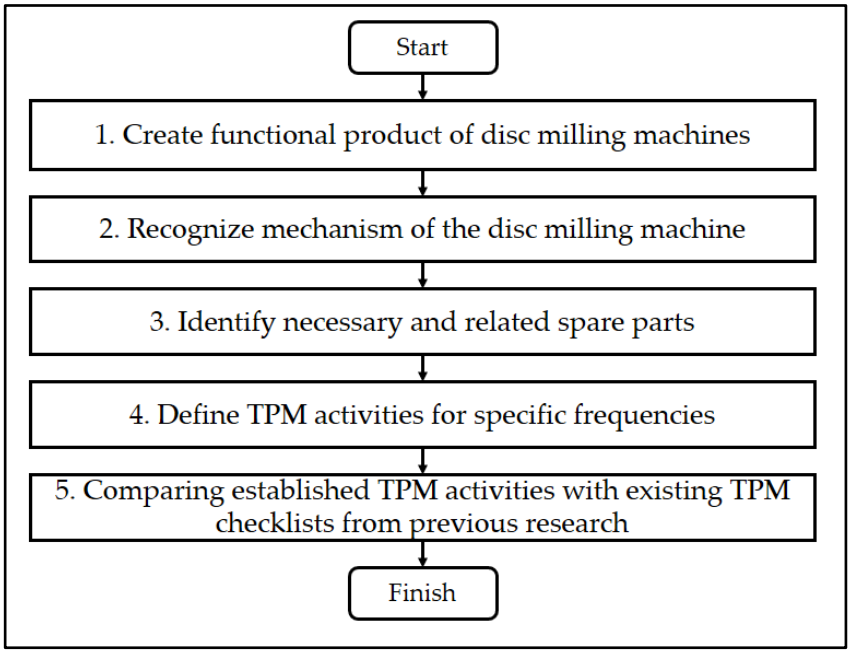

Figure 3. Research Flowchart

3. Results and Discussion

According to research flowchart presented in **Figure 3**, there are three main activities. Research started from creating functional product diagram of disc milling machine, includes recognize mechanism and identify related spare parts. Then, defining TPM activities for each spare parts using functional based diagram. After that, comparing established TPM activities with previous research to validate the accuracy level.

3.1. Functional product diagram of disc milling machine

Making functional based diagram of disc milling machine started from creating block diagram and identifying the main function, related external sources, and expected output **[12].** Main function of disc milling machine is chopping raw material into powder by using knife **[13].** After creating functional based diagram, mechanism of the machine and related spare parts can be recognized easily. **Figure 4** and **Table 1** show the functional based diagram of disc milling machine and related spare parts respectively.

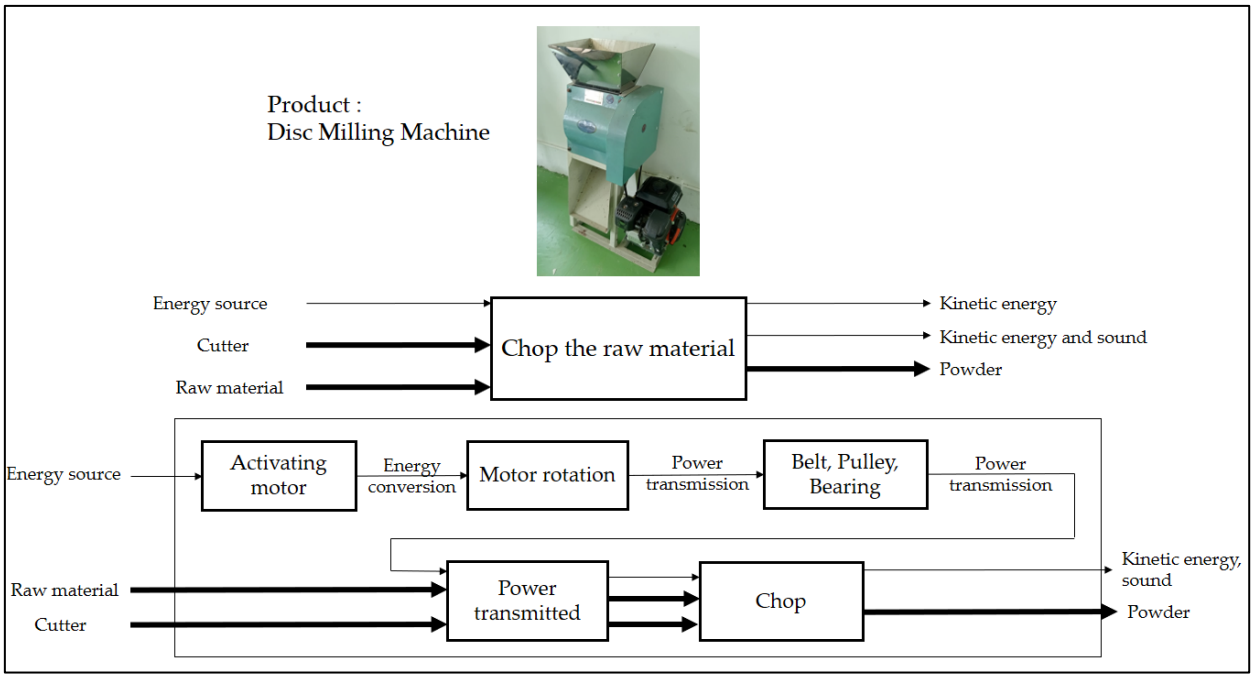

Figure 4. Functional based of disc milling machine

Table 1. Mechanism and spare parts of disc milling machines

Main function	Mechanism	Spare Part
Chop raw material into powder	Activate motor	Motor and its wiring system
	Transmit the power	Belt, Pulley, Bearing, Shaft
	Insert raw material	Hopper
	Chop raw material	Knife, knife holder
	Get the powder	Bowl, Filter

3.2. Develop TPM checklists for disc milling system

TPM checklists consists of autonomous maintenance (AM) and preventive maintenance (PM). These two pillars provide necessary activities that need to be conducted either by operators or technicians. In general, there are 4 main activities in maintenance; cleaning, lubricating, repairing, replacing **[14].** Those 4 activities need to be distributed into specific schedule, either in daily basis, weekly basis, monthly basis, quarterly basis, or yearly basis. There is numerous method to derive AM/PM activities into regular schedule, one of the mostly used method is ISMO (Inspection, Small Repair, Medium Repair, Overhaul) **[15-18]**. To separate AM and PM activities, figure 5 shows the simple guidance by connecting the line for each spare parts.

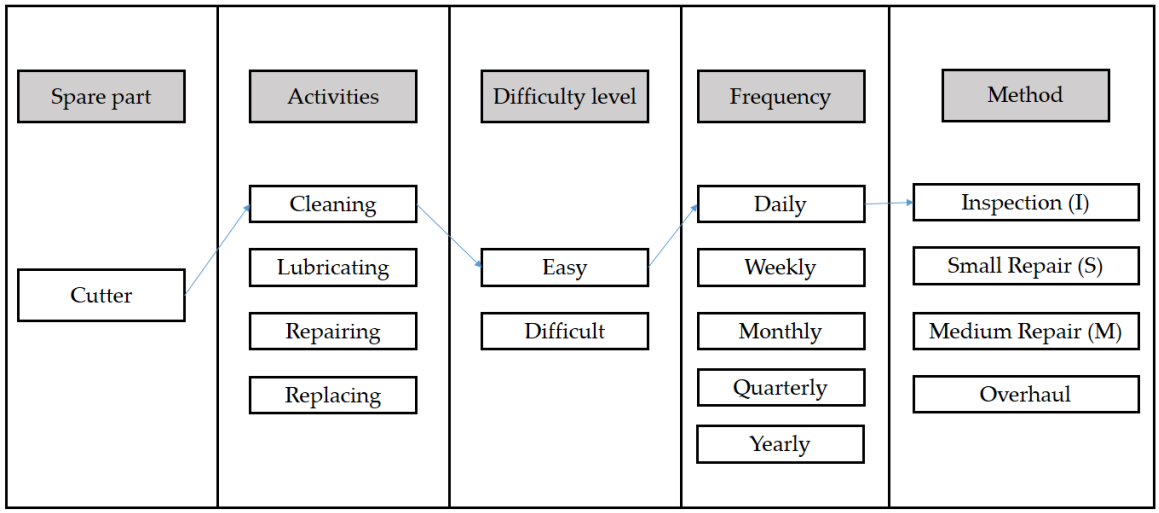

Figure 5. Line connection to derive AM/PM activities

If the activity is defined as easy one, and need to be performed daily, it will be autonomous maintenance (AM) checklists and becomes machine operator's responsibilities. If it is difficult to be executed and takes time, then it will be Preventive Maintenance (PM) checklists, and needs to be conducted by technician with specific skills and tools. Consideration for connecting the line in figure 5 can be a survey, observation, experience, previous research, interview, or common senses. **Table 2** presents the established AM checklist and PM checklists.

Table 2. AM/PM checklist activities

Area	Mechanism	Spare Part	Method	AM/PM
Main and supporting	Frame	Cleaning	Inspection	AM
	Bolt, nut, ring, joint	Cleaning, tightening	Inspection	AM
Driving system	Motor	Cleaning	Inspection	PM
Transmission system	Belt	Cleaning, tightening	Inspection, Small repair	PM
	Pulley	Cleaning, tightening	Inspection, Small repair	PM
	Bearing	Cleaning, tightening	Inspection, Small repair	PM
	Shaft	Cleaning, tightening	Inspection, Small repair	PM
Cutter	Knife	Cleaning, replacing	Inspection, Small repair	AM
	Knife holder	Cleaning, replacing	Inspection, Small repair	PM
Input	Hopper	Cleaning	Inspection	AM
Output	Bowl	Cleaning	Inspection	AM

3.2. Comparing established TPM checklists

In order to validate functional based approach, established TPM checklists from functional based approach is necessary to be compared with previous research **[19].** Accuracy level can be calculated by using equation 1. This approach is good if accuracy level more than 90%.

$$Accuracy\ Level = \frac{Total\ checked\ parts\ from\ functional\ based\ approach}{Total\ checked\ parts\ from\ previous\ research} \quad (1)$$

Table 3 presents the comparison of checked parts between functional based approach and previous research.

Table 3. Comparison of functional based approach and previous research

Area	Mechanism	Functional Based Approach	Previous Research
Main and supporting	Frame	v	v
	Bolt, nut, ring, joint	v	v
Driving system	Motor	v	v
	Fuel tank		v
Transmission system	Belt	v	v
	Pulley	v	v
	Bearing	v	v
	Shaft	v	v
Cutter	Knife	v	v
	Knife holder	v	v
Input	Hopper	v	v
Output	Bowl	v	v
Total checked parts		**11**	**12**

From comparison presented in **Table 3**, there was one missing checked parts. Therefore, the accuracy level is calculated using equation 1.

$$Accuracy\ Level = \frac{Total\ checked\ parts\ from\ functional\ based\ approach}{Total\ checked\ parts\ from\ previous\ research} = \frac{11}{12} = 91.67\%$$

Established TPM checklists should be updated regularly, it might be once a year or twice a year to align with production schedule **[20].** And also, spare parts and lubricant consumption during production and maintenance are also need to be documented properly for reducing maintenance cost due to excessive usage and inventory **[21].**

4. Conclusion

Developed TPM checklist using functional based approach reached 91.67% accuracy level compared to previous research. There was one missing part in the functional based approach. It might be due to the limitation of the functional based method or inadequate description of each activities during creating functional based diagram. However, 91.67% accuracy level indicates that the functional based approach can be an alternative solution to create and develop TPM checklists for self-customized technology.

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