International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

The Machine Tools Performance Rate Based on a Holistic Approach in Ecomaintenance Implementation

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***Abstract*---When a factory decides to implement ecomaintenance for the first time, there is a test that the factory needs to do to examine the initial performance of a system that it uses. As an important component of a factory's system, machine tools receive a special concern to do it. The complexity of machine tools becomes the main reason to employ a holistic approach to assess the performance of the machine tools. The mechanical, metrological and electrical characteristics of machine tools are used to assess their operational performance using a holistic approach. After these machine tools have been tested mechanically with SNI and ISO Standards, their electrical and metrological characteristic are then tested by conducting several mechanical testing using a number of research samples. The results of the initial performance test found that there are 2 (two) machines in a good-condition category, 3 (three) machines in a fair-condition category and 1 (one) machine in a poor-condition category .The initial operational performance of machine samples will be used as a reference for the measurement of the success of ecomaintenance program implementation in a factory's system.**

***Keywords*---ecomaintenance; performance; machine; tools; holistic**

I. INTRODUCTION

Ecomaintenance is a concept of maintenance with new paradigm related to economic values obtained by well-maintained machines and their contribution toward environmental conservation. The effect is the machines are reliable, so that they create a stable, energy saving and pollutant-free production system. The well-maintained machine has higher economical value because it can produce smoothly and avoid opportunity loss to get profit due to machine error. The product quality is more maintained because the process of production runs as planned. Different from conventional maintenance, ecomaintenance does achievement level measurement of machine performance by comparing the initial performance of the machine to the machine performance in a certain period after the system is applied. Ecomaintenance measures the level of its success by viewing the energy saving occurs as the indicator of the amount of energy cost saving and pollutant reduction which can be done [1].

When ecomaintenance is implemented, the initial performance assessment is conducted. As the main component of a manufacture system, the performance assessment is also done to machines. It aims at finding out the initial condition of the machine before being maintained and determining a reference to find out the achievement level of the applied maintenance process. The success level is shown by some performance indicator which is determined in the initial maintenance process. These indicators will show how the impact of maintenance treatment toward machine performance after the maintenance system is applied by evaluating its performance in a certain period. The performance assessment is done either for new machines or old machines. The procedure of ecomaintenance maintenance into a system can be seen in Figure 1.

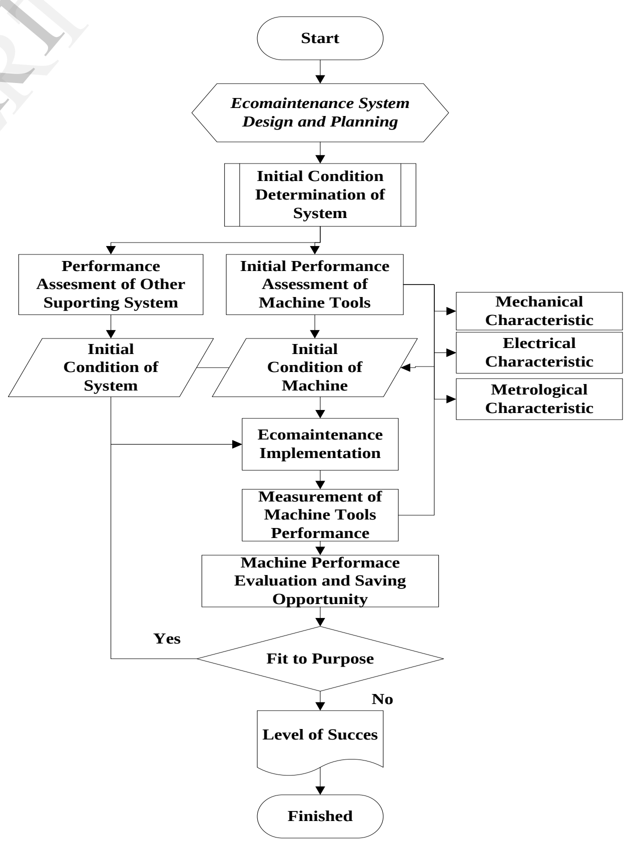

Fig. 1. Procedure of *Ecomaintenance* System Implementation

In a general way, OEE application is limited in semi-automatic and full-automatic assembling, so that the application on manual assembling often finds difficulties [2]. The measurement of full machine performance is needed, based on the calculation of all losses occur [3]. Special approach to machine tools in performance assessment is necessary to be done because machine tools, is generally complex machines with many variances. The holistic approach which is applied when doing machine tools performance assessment is based on three main characteristics, i.e. mechanical characteristic, metrological characteristic and electrical characteristic. The three characteristics have impacts on machine power performance, cutting rate, accuracy and reliability [4]. The mechanical characteristics of machine tools can be seen in the way of calibrating according to the recommendation from OEM (*Original Equipment Manufacturer*)-produced factory or determined standards (ISO , DIN, JIS and so on). When the mechanical characteristics decrease or be disrupted, the machine cannot produce the components according to dimensional accuracy and geometrical accuracy determined according to initial production of the machine. The decrease of mechanical characteristics will also impact on the decrease of electrical performance and power consumption increase from it should be in the indicators. This impact also occur on metrological criteria, i.e. the decrease of configuration quality of surface or the increase of product roughness resulted in vibration while machining process.

II. METHODOLOGY

The steps of the initial performance assessment of machine tools will be done as described in flowchart in Figure 2.

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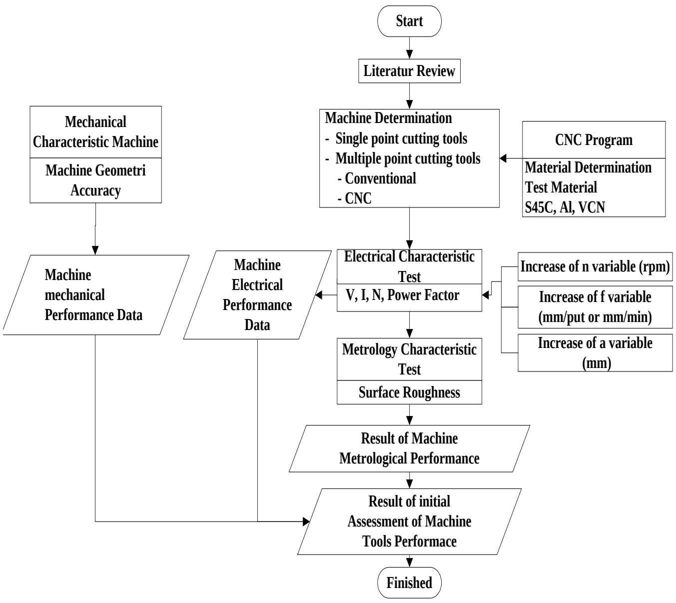

Fig. 2. Initial Machine Performance Assessment

The measurement of initial performance of machine tools will be done in 2 (two) conventional lathes with the same type and producing factory, 2 (two) conventional milling machines with the same type and factory, as well as 1 (one) CNC milling machine owned as the initial data of the implementation of ecomaintenance system. System performance measurement is started by testing machine tools performance existing in manufacture system. The machine tools which are used as testing machine in this research have respective specification of machine types tested as many as 2 machines with the same machine type. The test machine tools can be seen in Figure 3 with the specifications as follows:

- Lathe Machine

1. Type : CT 404 T (B1, B2 and B3)
2. Total motor power : 5.5 KW
3. Work Volume : Φ270mm x 750 mm

- Milling Horizontal Machine (M2 and M3)

1. Type : FU 251
2. Total Motor Power : 5.5 KW
3. Work Volume : 1125 x250 x140 mm

- CNC Milling Vertical Machine (M1)

1. Type : OKUMA MB 46 VAE -R
2. Total Motor Power : 11 KW
3. Work Volume : 560 x 460 x 460 mm

Fig. 3. Test Machine Tools

A. *Measurement of Machine Tools Mechanical Performance*

Mechanical measurement for lathe machine is done by calibrating the machine by using SNI 05-1618-1989 while for milling machine it uses ISO 1984-1-2 standard.

B. *Measurement of Machine Tools Electrical Performance*

1) *Scheme of Testing on Lathe Machine*

The measurement of machine tools electrical performance is done by doing machining in test machine tools. In lathe test, machining process is done based on some parameters as written in Table 1 to Table 6 and by using test materials as described in Figure 4 to Figure 5. Test material machining and data collecting in various parameters of tested process are adjusted to three charts of research done, i.e.:

a) Test 1; the variable tested is spindle rotation with its fixed parameter is cutting depth, i.e. 0.5 mm and the feeding movement is 105 mm/rot. The size of spindle rotation variable can be seen in Table 1.

TABLE I. SCHEME OF RESEARCH 1 LATHE

Spindle Rotation							
125	180	250	355	500	710	1000	1400
Cutting Depth							
0.5							
Feeding Speed (Mm/min)							
105							
Feeding Movement (mm)							
0.105							

b) Test 2; the tested variable is feeding movement with the parameter is cutting depth of 0.5 mm and spindle rotation of 1000 rpm. The size of feeding movement variable can be seen in Table 2.

TABLE II. SCHEME OF RESEARCH 2 LATHE

Speed (mm/min)							
70	80	95	118	131	140	1190	280
Feeding Movement (mm/rot)							
0.07	0.08	0.095	0.118	0.131	0.14	1.19	0.28
Cutting depth							
0.5							
Rotation (rpm)							
1000							

The test materials of testing 1, 2 and 3 are taken with materials Al, S45C, and VCN with the dimension of Φ29x 150 mm. Geometry from the test materials in test 1 and 2 can be seen in Figure 4.

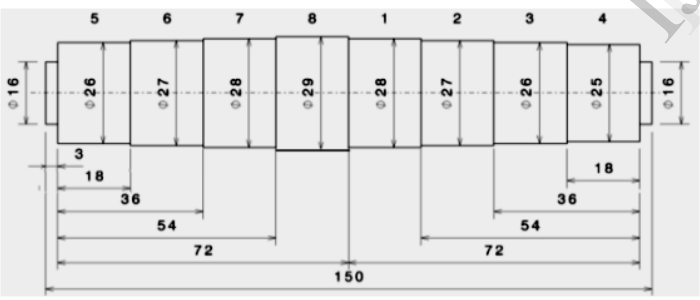

Fig. 4. Test Materials of Research 1 and 2

c) Test 3; the variable tested is the cutting depth with the fixed parameter is the spindle rotation of 1000 rpm and feeding movement of 0.105 mm/rot. The size of cutting depth variable can be seen in Table 3.

TABLE III. SCHEME OF RESEARCH 3 LATHE

Cutting Depth							
0.025	0.5	0.75	1	1.25	1.5	1.75	2
Feeding Speed (mm/min)							
105							
Feeding Movement (mm)							
0.105							
Rotation (rpm)							
1000							

The test material in the test 3 can be seen in Figure 5.

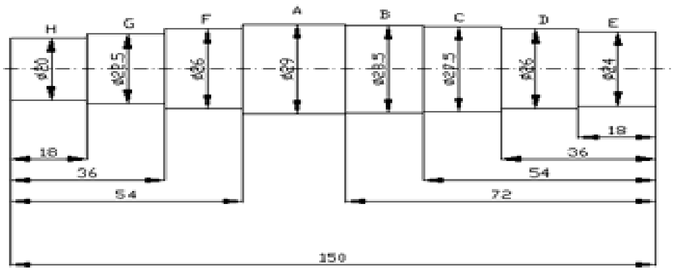

Fig. 5. Test Materials of Lathe Research 3

2) Testing Scheme in Milling Machine

The test material machining and data collecting on various parameters of the tested process in milling machine are adjusted to three charts of the research done, i.e.:

a) Test 1; the tested variable is the spindle rotation with the fixed parameter is the cutting depth of 0.4 mm and the feeding movement of 40 mm/min. The size of spindle rotation variable can be seen in Table 4.

TABLE IV. SCHEME OF MILLING RESEARCH 1

Spindle Rotation								
125	300	490	590	725	945	1225	1500	1800
Cutting Depth								
0.6								
Feeding Speed (mm/min)								
40								
Feeding Movement (mm/rot)								
0.160	0.067	0.041	0.034	0.028	0.021	0.016	0.013	0.011

b) Test 2; the tested variable is the feeding speed with the fixed parameter is the cutting depth of 0.4 mm and the spindle rotation of 945 rpm. The size of feeding speed variable can be seen in Table 5.

TABLE V. SCHEME OF MILLING RESEARCH 2

Feeding Speed (mm/min)								
35	40	50	65	85	105	125	165	205
Feeding Movement (mm/rot)								
0.01 9	0.02 1	0.02 6	0.034	0.0 45	0.05 6	0.06 6	0,08 7	0.0125
Cutting depth								
0.6								
Rotation (rpm)								
945								

c) Test 3; the tested variable is the cutting depth with the fixed parameter is the spindle rotation of 945 rpm and the feeding speed of 40 mm/min. The number of cutting depth variable is stated in Table 6.

TABLE VI. SCHEME OF MILLING RESEARCH 3

Cutting Depth								
0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2
Feeding Speed (mm/rot)								
40								
Feeding Movement (mm/rot, gear) z = 2								
0.160	0.067	0.041	0.034	0.028	0.021	0.016	0.013	0.011
Rotation (rpm)								
945								

The test material that will be used in milling machine can be seen in Figure 6. In machining test in the milling machine, there are three samples with the type of materials are S45C, VCN, and Al and the bar specimen size is 128 x 80 x 15 mm

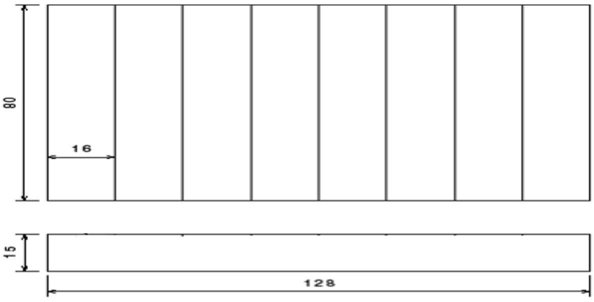

Fig. 6. Test Material of Milling Research

C. *Measurement of Metrological Characteristics of Machine Tools Performance*

In the measurement of metrological performance, the roughness of product surface that is the result of mechanical performance and electrical machine results will be taken. The roughness of the product surface is the quality representation of the product produced by machines. The measurement of the surface roughness toward 9 material test of 3 types of research and 3 kinds of materials, i.e.: VCN, S45C and Al. The measurement of surface roughness (Ra) is done in every number of test material surface as the result of experiment, rotated in athway in 5 times to get different position of the sample. The method of measurement and the length of the sample refer to standard ISO 4288. The measuring tools used in this research can be seen in Figure 7.

Fig. 7. Testing Measurer

Remarks

1. Calipers
2. Micrometer
3. Mandrel
4 Watt Meter
5. Dial indicator
6. Dial indicator bearing
7. Spirit level (water pass)
8. Tang Amper+cosphi
9. Mitutoyo Surftest 301

III. RESULTS AND DISCUSSION

The testing on the three lathe machines uses 13 test types in Indonesia National Standard 05-1618-1989 [3]. After the results of measurement quantitatively are obtained, then qualitative assessment is done to obtain the category of machine. The categorization is conducted by referring to the amount of the testing results which is derived from tolerance of the standard value determined in SNI 05-1618-1989 or ISO 1984-1-2, the provision of the assessment are determined like in Table 7. The assessment in Table 7 based on considerations that if the test results from standard value are still in few number, i.e. <u><</u>3 and with the substitution or minor set up which the machine can still be repaired, it is categorized as in medium condition. However, if the deviation of the test result > 3 and it needs major improvement, the machine is categorized in bad condition.

TABLE VII. CATEGORY OF MECHANICAL CHARACTERISTIC ASSESSMENT

No	Test Results from Standard Value of SNI 05-1618-1989 or ISO 1984-1-2	Category	Score
1	0	Good	3
2	≤3 test result from standard value and or tol deviation can be improved	Medium	2.55
3	>3 test result from standard value and or tol deviation cannot be improved /re-arranged	Not Good	1

The electrical machine characteristics represent electrical performance of machine tools. The assessment uses three power assessments, i.e. machine starting power value (Nst), idle power value (Nmo), and machining power value. The data of the three powers above are taken in the experiment as explained in research methodology. The rules of electrical characteristic assessment can be seen in Table 8.

TABLE VIII. RULES OF ELECTRICAL CHARACTERISTIC ASSESSMENT

No	Power Testing Result	Condition	Category	Score
1	Starting Power (Nst)	Normal	Good	3
		Nst up 5% ≤Nst Normal ≤ Nst up 10%	Medium	2.55
		> Nst 10% up	Wasteful	1
2	Idle Power (Nmo)	Normal	Good	3
		Nmo up 5% ≤Nmo Normal ≤ Nmo up 10%	Medium	2.55
		> Nmo 10% up	Wasteful	1
3	Machining Power (Nmc)	Normal	Good	3
		Nmc up 5% ≤Nmo Normal ≤ Nmc up10%	Medium	2.55
		> Nmc 10% up	Wasteful	1

Metrological characteristic assessment is represented by the assessment of surface roughness of machining product following the rules of DIN standard 4768 part 2.

The range of this roughness value also represents machine quality and its machining. The rules of quality assessment as stated in Table 9.

TABLE IX. RULES OF METROLOGICAL CHARACTERISTIC ASSESSMENT

No	Machining Process	Surface Roughness Ra (µm)	Category	Score
1	Lathe	Ra<0,4	Smooth	3
		0,4<Ra<6,3	Normal	2.55
		Ra>6,3	Rough	1
2	Milling	Ra<0,8	Smooth	3
		0,8<Ra<6,3	Normal	2.55
		Ra>6,3	Rough	1

Based on the results of the experiment, it is obtained that electrical and metrological characteristic data represented by power consumption and product surface roughness of machining results. The data can be seen in Table 10.

TABLE X. EXPERIMENT RESULT DATA OF ELECTRICAL AND METROLOGICAL CHARACTERISTICS

No	Unit Machine	Nst (Watt)	Nmo (Watt)	Nmc (Watt)	Ra (μm)
1	B1	700	950-1325	1600-2000	0.16-6.3
2	B2	675	975-1650	1725-2025	0.5-6
3	B3	850	1450-1850	2275-2600	0.7-10
4	M1	630	700-1950	910-2580	0.16-3.75
5	M2	1160	3450-4670	3770-4680	0.16-3
6	M3	1600	3450-4640	4000-4690	0.5-8.5

The results of electrical machine performance can be seen in Table 11.

TABLE XI. ELECTRICAL MACHINE PERFORMANCE

No	Name Machine	Nat %	Nmo Min (%)	Nmo Max (%)	Nmc Min (%)	Nmc Max (%)	P (%)
1	B1	85	100	100	100	100	97
2	B2	100	85	33	85	85	78
3	B3	33	33	33	33	33	33
4	M1	100	100	100	100	100	100
5	M2	100	100	85	100	100	97
6	M3	33	100	100	3	100	67

The initial research results of [5] and [6], it is found that there is adjustment between maintenance system received by machine and consumption pattern of machine energy as the effect of machine electrical performance. In the milling machine of M1, M2 and lathe machine of B1, it seems that there is power needed for an for the lowest machining if compared to the same machines. These three machines are maintained according to the procedure so that they will be more energy saving. On the other hand, in the M3 milling machine and B2 lathe machine although the machine is maintained, there are some conditions which are not in accordance with the procedure, so that the electrical performance decreases and the machine power consumption becomes higher than it should be. In B3 lathe machine, the machine will be treated or maintained for last years, as a result, the electrical performance decreases, and the power consumption is wasteful. Furthermore, according to OEE (*Overall Equipment Evaluation*) formulation, machine electrical performance value obtained will be multiplied with stock value and quality value of the product so it is obtained that the operational performance value of the machine. The operational performance value can be seen in Table 12.

TABLE XII. OPERATIONAL PERFORMANCE VALUE FROM THE TEST

No	Machine Name	Number of Test unfit with Tol. Requirements	A (%)	Ra Product	Q (%)	P (%)	KO (%)
1	B1	1	85	0.16-6.3	100	97	82
2	B2	3	85	0.5-6	93	78	61
3	B3	5	33	0.7-10	33	33	4
4	M1	0	100	0.16-3.75	100	100	100
5	M2	0	100	0.16-3	100	97	97
6	M3	3	85	0.5-8.5	93	67	53

Operational performance of the machine assessment also considers the results of observation and comparison with real operational performance of the machine in the factory. Based on the results above, then 3 categories of operational performance of the machine are determined. They are machine with KO value > 80%, with good operational performance, in good machine condition. The machine with the value of 50% $\leq$ KO $\leq$80% has medium operational performance, medium machine condition. The machine with KO value <50% is the machine whose less good operational performance and in less good condition.

Based on Table 12, it is found that machines whose high performance value are M1 milling machine whose KO value of 100%, M2 milling machine whose KO value of 97%, and B1 lathe machine whose KO value of 82%. The three machines are in good condition. The two lathe machines, B2 whose KO value of 61%, and M3 milling machine whose KO value of 53%, are medium condition machine. B3 lathe machine has KO value of 4% is less good operational performance machine and it is in less good condition. Furthermore, the data obtained will be used as the reference in planning and implementing ecomaintenance strategy. The substitution of some components which are worn out or in less good condition will be rearranged.

IV. CONCLUSION

Operational performance assessment approach holistically is a systematic method but it is easy in assessing the performance of machine tools. In general, the machine tools have complex design to support multifunction tasks so the assessment with general OEE method is less appropriate. However, by using holistic assessment covers mechanical, electrical, metrological characteristic assessment can be more accepted. The three characteristics obtained can describe the electrical availability, quality and performance of the machine and they become input to find out operational performance of the machine. The operational performance of this machine becomes the input in determining appropriate maintenance strategy in ecomaintenance machine tools system.

Based on the results of testing on 6 (six) machine tools above, it can be concluded that there are 3 (three) machines whose good operational performance, i.e. M1 milling machine (CNC milling), (M2) and B1 lathe machine. The 2 (two) machines have medium operational performance , i.e. B2 lathe machine and M3 milling machine whose medium performance, while B3 lathe machine whose less good operational performance.

ACKNOWLEDGMENT

This paper is the result of a research in the third year of PUPT entitled "Autonomous Audit Model for Energy Consumption Saving of Machine Tools" funded by the Ministry of Education and Culture of the Republic of Indonesia through Budget Implementation Authorization (DIPA) of Kopertis Region III Jakarta with DIPA No.: 180/K3/KM/2014, dated 7 May 2014.

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