Formosa Journal of Sustainable Research (FJSR)
Vol.2, No.7, 2023: 1627-1636

Condition Monitoring Scheduled Oil Sample on Crane Machine Using the Fuzzy Logic Methode

Syaiful Rizal[1]*, Kartika Sekarsari[2]
[1]Prodi Teknik Mesin, Fakultas Teknik Universitas Pamulang
[2]Prodi Teknik Elektro, Fakultas Teknik Universitas Pamulang
Corresponding Author: Syaiful Rizal syaiful.rizal.108@gmail.com

A R T I C L E I N F O

Keywords: Fuzzy Logic, Scheduled Oil Sample, Crane, Machine

Received : 5 June
Revised : 21 June
Accepted: 22July

©2023 Rizal, Sekarsari: This is an open-access article distributed under the terms of the Creative Commons Atribusi 4.0 Internasional.

A B S T R A C T

Maintenance of crane engines in the mining world is very much needed to maintain the engine in good condition and function when used. In crane engine maintenance management, a scheduled oil sample is a form of predictive engine maintenance by taking regular oil samples from the engine to analyze its content and quality in the laboratory. The Fuzzy Logic method used in this study aims to monitor the results obtained from the laboratory so that it can be recognized that the condition of the engine is still in excellent condition (eval A), the state of the engine is still good, and no action has been recommended (eval B), it is recommended action on the engine (eval C) and recommends stopping the engine (eval X)

DOI: https://doi.org/10.55927/fjsr.v2i7.5289
ISSN-E: 2830-6228
https://journal.formosapublisher.org/index.php/fjsr

INTRODUCTION

In the mining world, heavy equipment is critical and needed. Therefore the best equipment products are always sought to support mining operations). One of the heavy equipment products is the Mobile Crane AC 200, which has a lifting power of 200 tons. Considering that this equipment's function is critical, spare parts availability for these components must be considered. Therefore, a reliable maintenance system is needed to monitor the components that use oil as a lubricant, such as an engine, transmission, hydraulic system, and final drive, so that the components are already available if an overhaul is held(Samsinar et al., 2019),(Utomo & Santoso, 2022).

Schedule Oil Sampling (SOS) is a method often used to monitor the condition of engine components by taking engine oil samples periodically so that the content and quality can be analyzed in the laboratory. An oil sample result schedule (SOS) indicates the condition of engine components and the time required to prepare parts. Thus there are no more delays in waiting for spare parts so that downtime can be reduced, and equipment reliability can be maintained(Raposo et al., 2019).

Fuzzy logic is a problem management method suitable for simple to complex systems. The artificial intelligence system Prof. Lotfi Zadeh first discovered has several processes: mapping fuzzy sets, applying IF-THEN rules, and fuzzy inference processes (Serrano-Guerrero et al., 2021),(Zadeh, 2008). In artificial intelligence (AI) systems, fuzzy logic can imitate human reasoning and cognition, where 0 and 1 are entered as extreme truth values but with various intermediate truth levels. It is well suited for a reasoning approach, especially for systems that deal with problems that are difficult to define using a mathematical model. Fuzzy logic is generally applied to problems containing uncertainty, inaccuracy, Etc(Zadeh, 2008).

This research uses the Fuzzy Logic method to analyze and monitor a mobile crane's components approaching failure conditions to obtain optimal and accurate monitoring conditions and information to detect early failures. Furthermore, the maintenance of a damaged Mobile Crane can be performed.

Overview of Maintenance Systems

Maintenance is described as all activities conceptualized to maintain the quality of the machine/equipment to remain reasonable and to ensure unit functionality during uptime and minimize downtime caused by damage or failure so that the machine can function as in its initial condition. The objectives of the machine maintenance system include; extending the life of machine assets, ensuring optimal availability of installed equipment, ensuring the operational readiness of all equipment required in an emergency at any time, and ensuring the safety of the people who use the equipment(Kosasih et al., 2019),(Imtihan & Yusup Somantri, 2022).

Three important things to assess the efficiency and maintenance performance of a system or equipment, among others, are: Reliability is the probability of an item generally working during operation (Wicaksono et al., 2021),(Ren, 2021). Availability is the availability of an item to work, typically when operational (Thawkar et al., 2018), (Wulansari & Ardyanto W., 2019).

Maintainability is the probability of maintaining an item to be returned to its initial operational condition (Ulugbek et al., 2018).

In reliability techniques, the bathtub curve determines the failure rate based on time. The bathtub curve has 3 phase periods: Early Failures, shown at the rate of damage that is initially high, decrease with increasing time, or Decreasing Failure rate (DFR). Useful Life, in this period, has the lowest and almost constant damage rate, called the constant failure rate (CFR),(Bhardwaj et al., 2019),(McLinn, 1990). The damage that occurs is random. Wear out in this period. The failure rate increases proportionately to the number of working hours that have started to be high. This condition will continue to rise until it reaches its peak when the equipment or component has been damaged and is not to be used anymore. The analysis used in this research is based on the bathtub curve (Nadjafi et al., 2018), (Shetty, 2018) . The curve of the bath is shown figure 1.

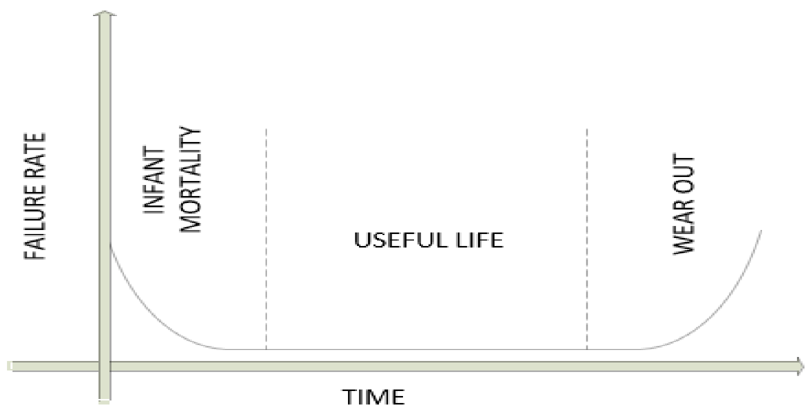


Figure 1. Bathtub Curve

METHODOLOGY

The method consists of three-step, namely: the oil sample taking the step, the oil sample schedule step, and the design step using Fuzzy Logic.

1. Oil Sample Taking the Step

The initial step of the research was taking oil samples. The following is the procedure for taking the correct oil sample.(Zhu et al., 2013)

a) Ensure that the sample points are free of dirt and contamination
b) Mark sample points so that all technicians collect samples from the same location.
c) Take a sample when the oil is at its operating temperature.
d) Clean plug/dip area
e) Take, for example, circulating oil.
f) Insert the plastic pipe into the dipstick/oil sample taking hole, suck/flow approximately 100 ml into the drain cup, then discard (this process is useful so that the sample taken is clean.)
g) Put the plastic pipe back in the suction pump and fill 3 / 4 to the SOS bottle, not so full so as not to get into the dirt.

h) Pull the plastic pipe from the suction pump and close the sample bottle tightly, and do not forget to attach the completed label data to be sent to the SOS Laboratory.

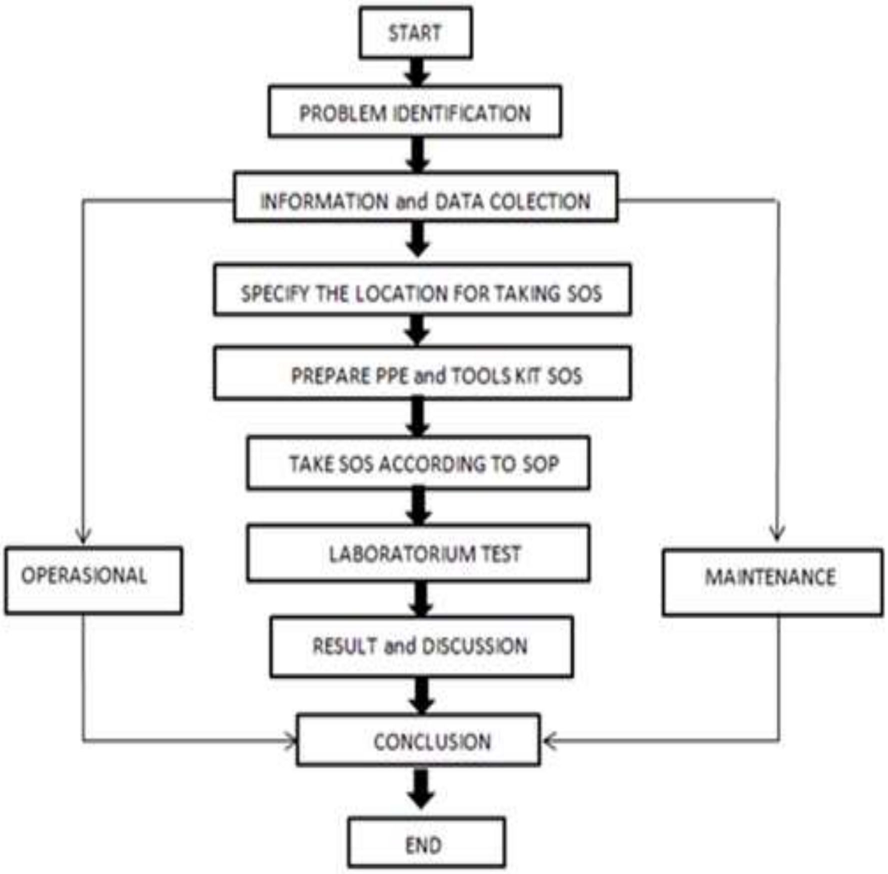


Figure 2. Flow Diagram of SOS, Condition Monitoring on Crane

The SOS flow chart procedure, Condition monitoring on the crane, which, as shown in Figure 2, is as follows:

a) Identification of problems with the increase in Fe element in wear metal.
b) Collecting supporting data as done utilizing field inspections.
c) Retrieve operation data and maintenance data.
d) Determine the location of the oil sampling, according to (SOP).
e) Use appropriate personal protective equipment, gloves, safety shoes, and equipment / SOS.
f) Take the oil stick, enter the new hose, go to the suction pump and into the stick about halfway into the oil pan position, take the oil not too full, fill it, and correctly the data on the accompanying bottle label (SOS).
g) Wear metal testing, oil quality testing (Oil Condition), contamination testing (Contaminant), viscosity testing.
h) Results and discussion of laboratory testing (SOS).
i) Identify engine conditions.

2. Oil Sampling Step

The Oil Sample Schedule method procedure includes:

a) Measure < 9-micron wear of metal
b) Oil Quality Analysis with Infrared
c) Measuring Viscosity
d) Calculating the Total Base Number (TBN)
e) Calculate the mass of ferrous debris in the sample

The SOS (Scheduled Oil Sample) program evaluation produces information based on the following table-1:

Table 1. Evaluation of the SOS Program

Eval	Description
A	Normal
B	(Reportable)has not been suggested action
C	Action recommended
X	Recommended to stop the engine

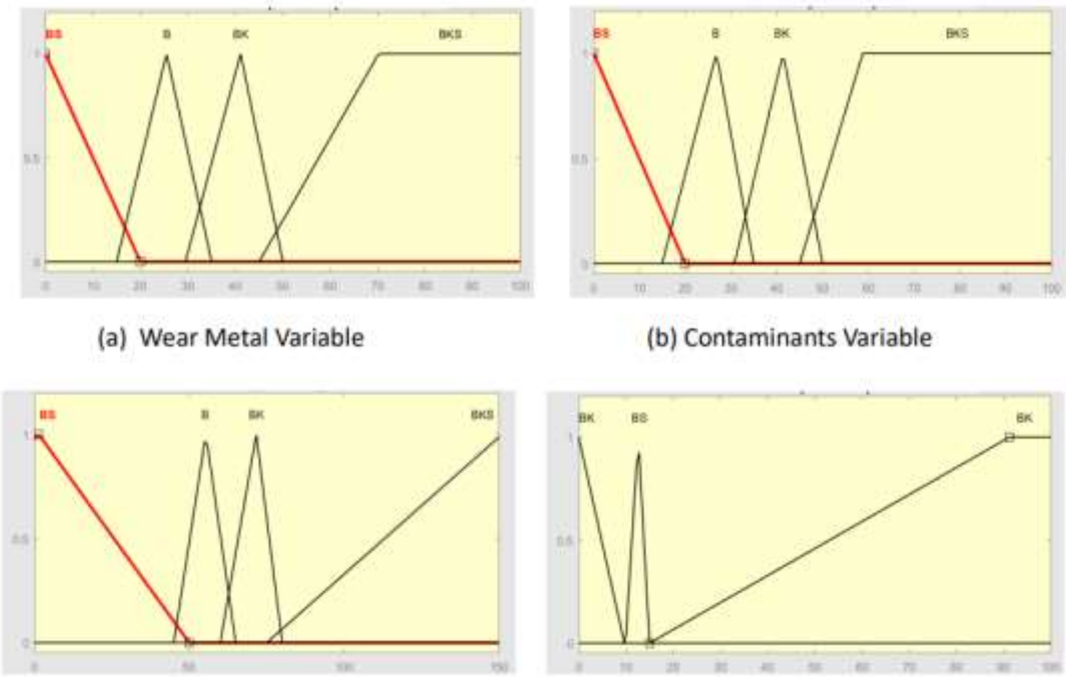
3. Fuzzy Logic Design Step

Table-2 shows a table of input and output variables of Fuzzy logic. The input variables consist of: wear metal, contaminants, oil quality, and viscosity. Meanwhile, the output variable monitors the range value engine condition as obtained from the oil condition test data. Fuzzy logic simulation using Matlab .

Table 2. Fuzzy Logic Parameters

LINGUISTIC VARIABLES			
Input	Wear Metal	Very Good (BS)	0-20
		Good (B)	15-35
		Bad (BK)	29-50
		Very Bad(BKS)	45-100
	Contaminants	Very Good (BS)	0-20
		Good (B)	15-35
		Bad (BK)	30-50
		Very Bad(BKS)	45-100
	Oil Quality	Very Good (BS)	0-50
		Good (B)	45-65
		Bad (BK)	60-80
		Very Bad(BKS)	75-150
	Viscosity	Bad (BK)	0-9.9
		Good (B)	9.9-15
		Bad (BK)	15-100
Output	Engine Condition Monitoring	Good (EVAL A)	0-75
		Good Monitor(Eval B)	75.1-99.9
		Repair (Eval C)	100-130
		Change (Eval X)	130-200

The variables membership function of the input and output as shown in Figure 3 and Figure 4.



(a) Wear Metal Variable (b) Contaminants Variable

(c) Oil Quality Variable (d) Viscosity Variable

Figure 3. Variables of Input

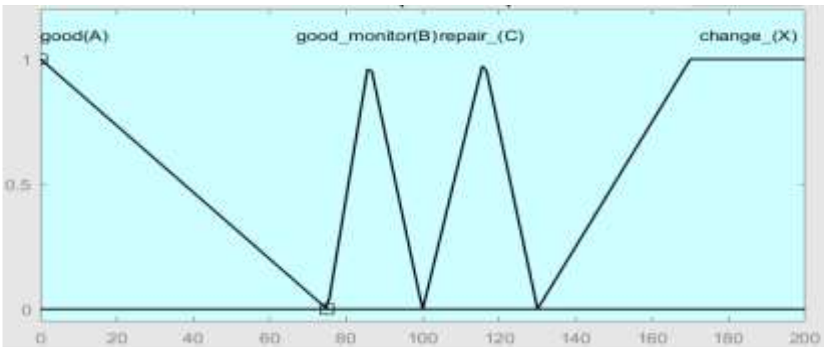


Figure 4. Variables of Output (Condition Monitoring Engine)

The application of fuzzy rules (Rule Base) in this study consists of 80 rules. The following are some examples of the rules base used in research.

[R1] *If* Wear Metal is BS *And Contaminant is* BS *And* Oil Quality is BS *And* Viscosity *is* BS *Then* Engine Condition Good (Eval A)

[R2] If Wear Metal is BS And Contaminant is B And Oil Quality is BS And Viscosity is BS Then Engine Condition Good (Eval A)

[R3] If Wear Metal is BS And Contaminant is Bk And Oil Quality is BS And Viscosity is BS Then Engine Condition Good/Monitor (Eval B)

[R4] If Wear Metal is BS And Contaminant is BkS And Oil Quality is BS And Viscosity is BS Then Engine Condition Repair (Eval C)

[R5] If Wear Metal is B And Contaminant is B And Oil Quality is BS And Viscosity is BS Then Engine Condition Good (Eval A)

[R6] If Wear Metal is B And Contaminant is B And Oil Quality is BS And Viscosity is BS Then Engine Condition Good (Eval A)

RESEARCH RESULT

Table 3. Measurement Results of Oil Monitoring with Fuzzy

NO	Date	Input				Output	Remark
		Wear Metal	Contaminant	Oil Quality	Viscosity	Engine Condition Monitoring	
1	18/1/2013	29	11	61.78	10.56	87.2	Eval B
2	04/10/2013	13	10	45.85	13.21	47.8	Eval A
3	24/6/2013	10	11	46.41	13.69	54.7	Eval A
4	30/9/2013	8	9	46.79	13.4	58.7	Eval A
5	24/12/2013	10	6	46.66	12.84	57.4	Eval A
6	04/03/2014	7	8	45.42	13.11	41.7	Eval A
7	28/6/2014	8	5	47.35	12.69	64.3	Eval A
8	16/10/2014	9	3	48	13.13	70.3	Eval A
9	17/2/2015	8	7	46.99	12.91	60.7	Eval A
10	24/5/2015	12	15	44.82	12.35	35	Eval A
11	26/11/2015	15	16	44.56	12.28	35	Eval A
12	02/10/2016	11	7	48.59	13.22	35.1	Eval A
13	12/04/2016	11	16	44.85	13.77	35.1	Eval A
14	05/01/2017	9	14	44.61	13.01	35	Eval A
15	15/8/2017	7	12	43.99	13.39	34.7	Eval A
16	21/12/2017	9	11	44.98	12.8	35.1	Eval A
17	01/12/2018	9	13	39.71	12.82	33.2	Eval A
18	30/10/2018	18	6	33.17	13.17	31.9	Eval A
19	22/1/2019	29	12	51.48	12.36	87.2	Eval B
20	08/09/2019	20	8	51.87	12.25	87.1	Eval B
21	18/10/2019	27	14	52.85	11.63	87.2	Eval B
22	03/01/2020	18	6	53.71	11.9	87.2	Eval B

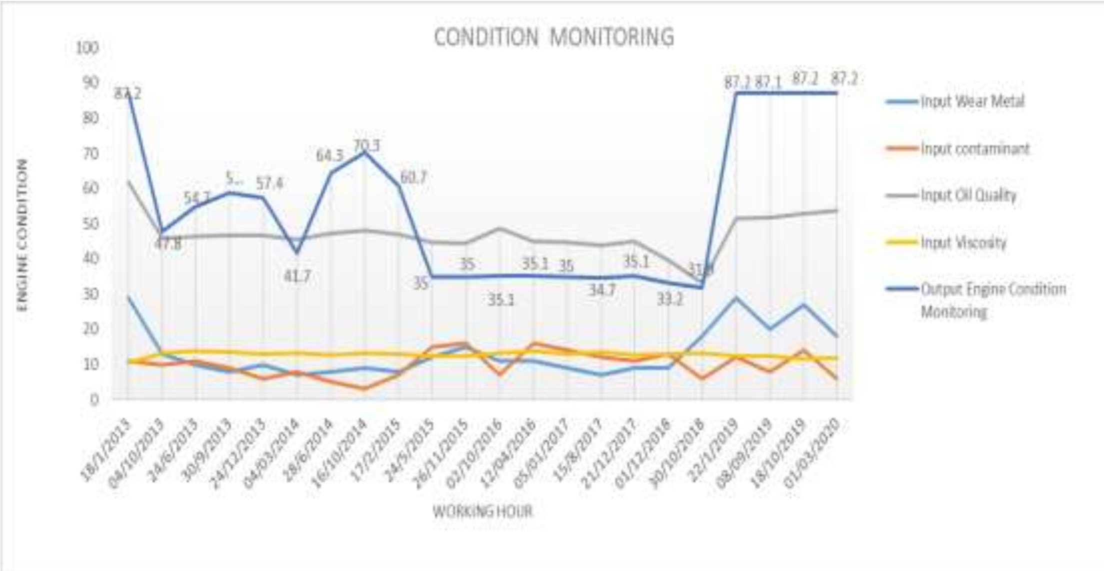


Figure 5. Graph of Condition Monitoring

DISCUSSION

Based on the values from Table 3 and Figure 5 for wear metal components, contaminants, oil quality, and viscosity, the results of monitoring engine conditions in the defuzzification method are as follows: For example, on 18/1/2013, the value of wear metal includes the sum of components (Fe, Al, Cr, Pb, Cu, Pq) yields a value of 29, this is in a suitable category (B). Contamination, which includes the sum of components (Si, Na, K, St), yields a value of 11. This as included in the Very Good (BS) category. The oil quality, which includes the sum of the components (Oxi, Nit, Sul, TBN), results in a value of 61.78, including the lousy category (BK). Viscosity 10.56 is a useful category (B). Thus the engine condition monitoring output is 87.2 with eval (B), likewise, for reading on the following data.

As shown in the previous table 2, that if the defuzzification value is in the range 0-75, then the engine condition monitoring will be at Eval A, whereas if the resulting defuzzification value is in the range 75.1 - 99.9, then the engine condition monitoring is at Eval B, and so on. Thus, it can as concluded that the fuzzy simulations made to monitor machine conditions are following the previously designed rule base based on fuzzy sets.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of monitoring with the Schedule Oil Sample (SOS) method using Fuzzy Logic, are as follows: (a)Fuzzy simulation as designed using the Fuzzy Mamdani method with linguistic variables consisting of several variables: wear metal, contaminants, oil quality, viscosity, and engine condition monitoring. Eighty rule bases as made to monitor the machine's condition so that it can as seen that the engine condition is in evaluation A, evaluation B, evaluation C, or evaluation X. (b) Based on the data table 3 the calculation results (defuzzification) at the SOS event 19,20,21,22, as shown with the engine condition monitoring output value of 87.2; 87.1; 87.2; 87.2 descriptions of eval B. If based on the bathtub curve, this trending enters the start wear out phase, which indicates that the engine is starting to go into a wear condition but is still in normal conditions.

ACKNOWLEDGMENT

Thank you to all parties who have supported and helped achieve this research so well that it can be published.

REFERENCES

Bhardwaj, S., Bhardwaj, N., & Kumar, V. (2019). The study of reliability of diesel locomotive engine using weibull distribution. *International Journal of Agricultural and Statistical Sciences*, *15*(2).

Imtihan, M., & Yusup Somantri. (2022). Perawatan Komponen Mesin Forming Untuk Meningkatkan Produksi Cup Minuman. *JENIUS : Jurnal Terapan Teknik Industri*, *3*(1). https://doi.org/10.37373/jenius.v3i1.230

Kosasih, W., Sriwana, I. K., & Purnama, W. J. (2019). Perancangan Sistem Informasi Perawatan Mesin Menggunakan Pendekatan Analisis Berorentasi Objek. *Jurnal Ilmiah Teknik Industri*, *6*(3). https://doi.org/10.24912/jitiuntar.v6i3.4246

McLinn, J. A. (1990). Constant failure rate — A paradigm in transition? *Quality and Reliability Engineering International*, *6*(4). https://doi.org/10.1002/qre.4680060405

Nadjafi, M., Farsi, M. A., Zio, E., & Mousavi, A. K. (2018). Fault trees analysis using expert opinion based on fuzzy-bathtub failure rates. *Quality and Reliability Engineering International*, *34*(6). https://doi.org/10.1002/qre.2313

Pislaru, M., Herghiligiu, I. V., & Robu, I. B. (2019). Corporate sustainable performance assessment based on fuzzy logic. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.03.130

Raposo, H., Farinha, J. T., Fonseca, I., & Galar, D. (2019). Predicting condition based on oil analysis – A case study. *Tribology International*. https://doi.org/10.1016/j.triboint.2019.01.041

Ren, Y. (2021). Optimizing Predictive Maintenance with Machine Learning for Reliability Improvement. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part B: Mechanical Engineering*, *7*(3). https://doi.org/10.1115/1.4049525

Samsinar, R., Almanda, D., & Priatna, E. (2019). Sistem Pengingat Ganti Oli Berdasarkan Running Hours Mesin, Lama Waktu Pemakaian dan Kekentalan Oli pada Mesin Wire Drawing Berbasis Raspberry Pi 1. *RESISTOR (ElektRonika KEndali TelekomunikaSI Tenaga LiSTrik KOmputeR)*, *2*(2). https://doi.org/10.24853/resistor.2.2.121-130

Serrano-Guerrero, J., Romero, F. P., & Olivas, J. A. (2021). Fuzzy logic applied to opinion mining: A review. *Knowledge-Based Systems*, *222*. https://doi.org/10.1016/j.knosys.2021.107018

Shetty, R. B. (2018). Predictive Maintenance in the IoT Era. In *Prognostics and Health Management of Electronics*. https://doi.org/10.1002/9781119515326.ch21

Thawkar, A., Tambe, P., & Deshpande, V. (2018). A reliability centred maintenance approach for assessing the impact of maintenance for availability improvement of carding machine. *International Journal of Process Management and Benchmarking*, *8*(3). https://doi.org/10.1504/IJPMB.2018.092891

Ulugbek, F., Buyun, S., Zheng, X., & Ismael, T. (2018). A reliability-based preventive maintenance methodology for the projection spot welding machine. *Management Science Letters*, *8*(6). https://doi.org/10.5267/j.msl.2018.5.005

Utomo, A. I., & Santoso, D. T. (2022). Implementasi FMEA (Failur Mode And Effect Analysis) Pada Mesin Bubut Konvensional Di PT. Raja Ampat Indotim. *Jurnal Teknik Mesin Dan Pembelajaran*, *5*(1). https://doi.org/10.17977/um054v5i1p17-24

Wicaksono, P. A., Saptadi, S., Nurkertamanda, D., & Rozaq, R. (2021). Production Machine Maintenance System Design Using Reliability Centered Maintenance. *IOP Conference Series: Materials Science and Engineering*, *1096*(1). https://doi.org/10.1088/1757-899x/1096/1/012018

Widyaningrum, M. R., & Winati, F. D. (2022). Penjadwalan Perawatan Mesin di CV Wijaya Workshop dengan Pendekatan Reliability Centered Maintenance (RCM). *Jurnal TRINISTIK: Jurnal Teknik Industri, Bisnis Digital, Dan Teknik Logistik*, *1*(1). https://doi.org/10.20895/trinistik.v1i1.455

Wulansari, N., & Ardyanto W., D. (2019). Hubungan Faktor Individu Dan Ketersediaan Prosedur Perawatan Mesin Dengan Tindakan Tidak Aman Oleh Mekanik. *The Indonesian Journal of Occupational Safety and Health*, *8*(1). https://doi.org/10.20473/ijosh.v8i1.2019.84-93

Zadeh, L. A. (2008). Is there a need for fuzzy logic? *Information Sciences*, *178*(13). https://doi.org/10.1016/j.ins.2008.02.012

Zhu, J., Yoon, J. M., He, D., Qu, Y., & Bechhoefer, E. (2013). Lubrication oil condition monitoring and remaining useful life prediction with particle filtering. *International Journal of Prognostics and Health Management*.