Fuzzy Logic Reliability Centered Maintenance

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Abstract: Reliability Centered Maintenence (RCM) is a sistematic maintenence strategy based on system reliability. Application of RCM process will not always come out with a binary output of “yes” and “no”. Most of the time they are not supported with available detail information to calculate system reliability. The fuzzy logic method attempts to eliminate the uncertainty by providing “truth” in different degrees. Data and responses from maintenance department will be processed using the two methods (reliability centered maintenance and fuzzy logic) to design maintenance strategy for the company. The results of the fuzzy logic RCM application are maintenance strategy which fit with current and future condition.

Keywords: Reliability centered maintenance, fuzzy logic

Introduction

Reliability Centered Maintenence (RCM) is a sistematic maintenence strategy based on a system reliability.RCM focused on failure prevention to maintain system’s functionality. The goal is to develop a maintenence strategy fit with current and future condition. Application of RCM process will not always come out with a binary output of “yes” and “no”. Most of the time they are not supported with available detail information to calculate system reliability.

The fuzzy logic method attempts to eliminate the uncertainty by providing “truth” in different degrees. According to Zadeh, a fuzzy set is a class of objects with a continuum of grades of membership. It has a membership function which assigns to each object a grade of membership between zero and one. Fuzzy logic RCM application will use information from maintenance department to design maintenance strategy which fit current and future condition.

Methods

Reliability Centered Maintenance (RCM)

RCM is a process used to determine the maintenence requirements of any physical assets in its operating contex. RCM has been used in the airline industry since 1970s and has been developed into non-aviation industry (nuclear power plants, oil refineries, water treatment plants, etc). There are seven basic RCM questions:

1. What are the functions of the asset in its present operating context?
2. In what ways does it fail to fulfill its functions?
3. What causes each functional failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?

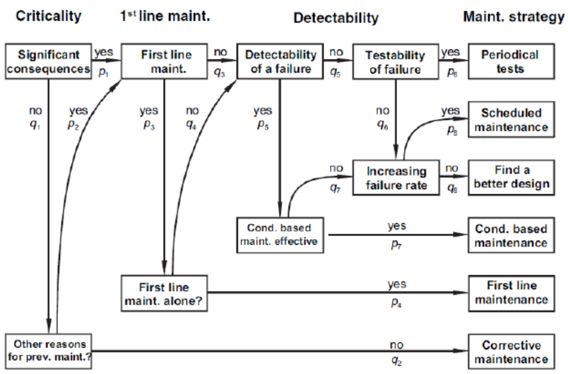

Figure 1. Example of RCM decission diagram

6. What can be done to predict or prevent each failure?
7. What should be done if a suitable proactive task cannot be found?

These seven questions resulted RCM decission diagram which will facilitate the choice of optimum maintenence strategy.

RCM itself has three approachs: qualitative, probabilistic, and fuzzy approach. Qualitative has its draw backs due to concensus requirements on each question and does not provide a ranking of strategies. Probabilistic approach interprets the degree of an expert’s belief as the mean value for a decission. Fuzzy aproach allows subjective assessment and expert experience as a fuzzy input variable.

Dampster-Shaffer Theory

Dampster-Shaffer Theory (DST), which also known as belief function theory, is a generalization of Bayesian theory for subjective probabilities. DST introduced in the field of reliability in the early 1990s. It is based on a scenario that contains the system with all hypotheses, pieces of evidence and data sources.

The hypotheses represent all possible states in the system. Pieces of evidence are symtoms or events that occur or may occur in the system. Data sources are persons or organizations that provide information for a scenario. There are several terms used in DST: basic assignment (m), belief (bel), and plausibility (pl).

$$bel\ A\ =\ {}_{B\subseteq A;B\neq\emptyset}\, m(B) \quad (1)$$

$$pl\ A\ =\ {}_{B\cap A\neq\emptyset}\, m(B) \quad (2)$$

$$m_{1,2}\ Z\ = \frac{{}_{A\cap B=Z\neq\emptyset} m_1\ A\ m_2(B)}{1-\ {}_{A\cap B=Z\neq\emptyset} m_1\ A\ m_2(B)} \quad (3)$$

Fuzzy Logic

Fuzzy logic is developed from the theory of fuzzy set by Lotfi Zadeh (1965). Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Fuzzy set used words and not number to represent certain condition like "no", "few", "some", "many", "yes". Membership function in fuzzy logic represent the degree of truth in the real world snd this will need a good formulation. There are a few type of fuzzy logic membership function, but triangular dan trapezoidal is the most commonly used.

Triangular membership function formed by three parameters (a,b,c) which (a<b<c).

$$Triangle\ x; a, b, c\ = \begin{matrix} 0, & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0, & c \leq x \end{matrix} \quad (4)$$

Trapeziodal membership function formed by four parameters (a,b,c,d) which (a<b<c<d).

$$Trapezoidal\ x; a, b, c, d\ = \begin{matrix} 0, & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ 1, & b \leq x \leq c \\ \frac{d-x}{d-c} & c \leq x \leq d \\ 0, & d \leq x \end{matrix} \quad (5)$$

Fuzzy Logic Process

Fuzzy logic has three steps in the process: fuzzification, rule evaluation, and defuzzification. Fuzzification is a process to transform crips values into grades of membership for linguistic terms of fuzzy set. The membership function is used to associate a grade to each linguistic term.

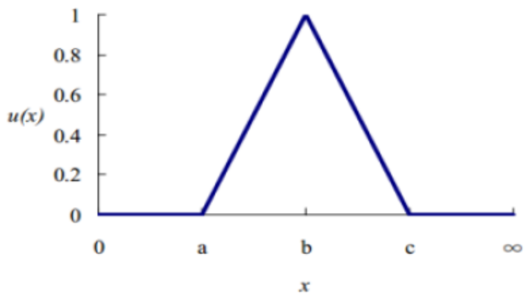

Figure 2. Triangular membership function

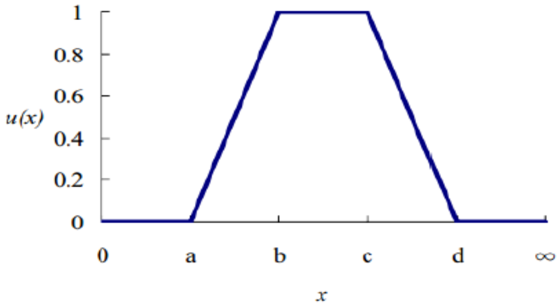

Figure 3. Trapeziodal membership function

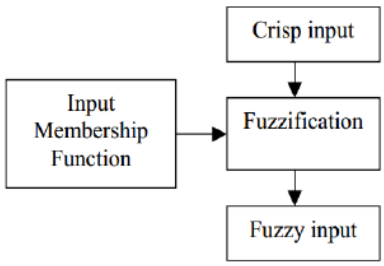

Figure 4. Fuzzification process

Rule evaluation is a process to to find fuzzy output from fuzzy input based on if_then rules.

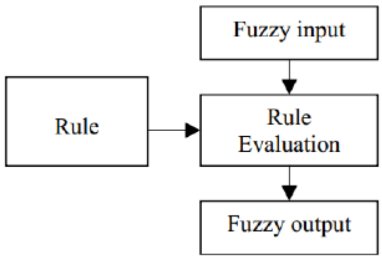

Figure 5. Rule evaluataion process

Defuzzification is a process to transform fuzzy output into crips outputusing output membership function.

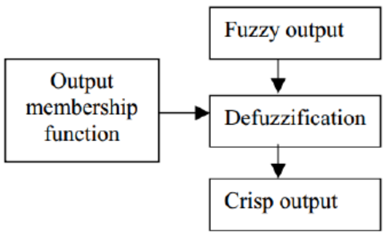

Figure 6. Defuzzification process

Results and Discussion

Failure Identification

Application of fuzzy logic RCM is held in an international thread manufacturing company in Surabaya, Indonesia. There three type of machine used in the process of thread manufacturing: doubling, twisting, and winding machines. Each machine is identified for component failure which caused the production stopped. This company used four type of maintenance: preventive maintenance, corrective maintenance, condition based maintenance, dan breakdown maintenance. RCM decision diagram is build based on maintenance system available in the company.

Decission to use certain type of maintenance for each failure most of the time is based on experience of the maintenance staff in the company. Most of the time there is no absolute "yes" or "no" for every question asked in this RCM decision diagram. Fuzzy logic will be used to solve the problem by giving degree of truth gradually.

Fuzzy inference model requires: fuzzy input output variable, membership function and if_then rules. Fuzzy input variables consist of: failure effect, failure pattern, failure symptom. Input membership function is build by creating linguistic label for each input variable. The label for failure effect started from "very low", "low", "medium", "high" and "very high". The label for failure patern and failure symptom started from "very clear", "clear", "medium", "not clear" and "very not clear".

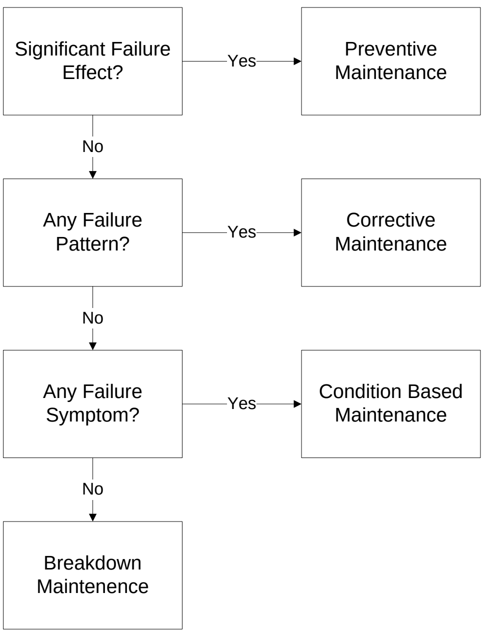

Figure 7. RCM decission diagram

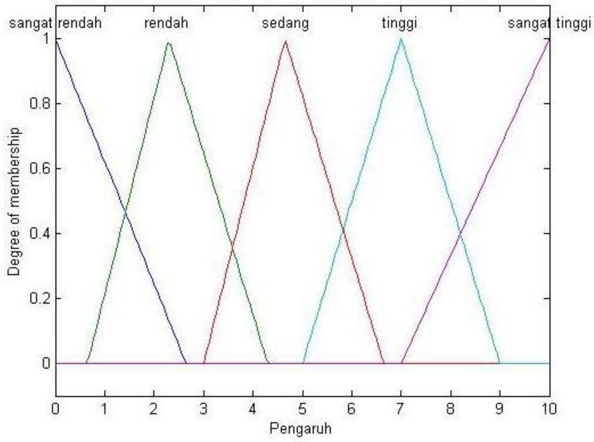

Figure 8. Membership function of failure effect

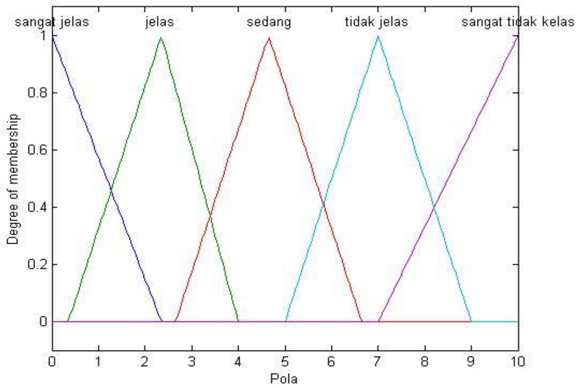

Figure 9. Membership function of failure pattern

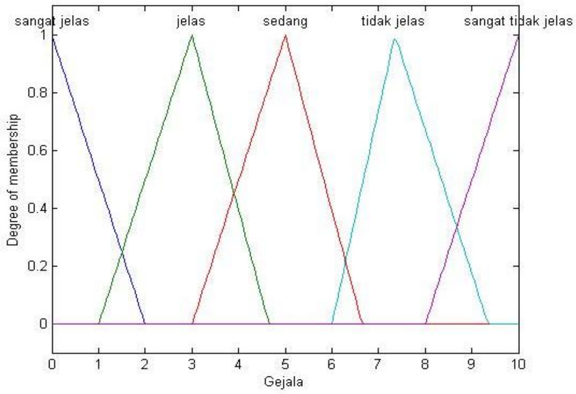

Figure 10. Membership function of failure symptom

There are 72 rules based on combination of the input variables. These rules used to decide type of maintenance based on fuzzy output variables. Since there are four type of maintenance used in the company, output variables also devided evenly to accommodate this.

- Preventive maintenance, between 0 and 2.5.
- Corrective maintenance, between 2.5 and 5.
- Condition Based Maintenance, between 5 and 7.5.
- Breakdown Maintenance, between 7.5 and 10.

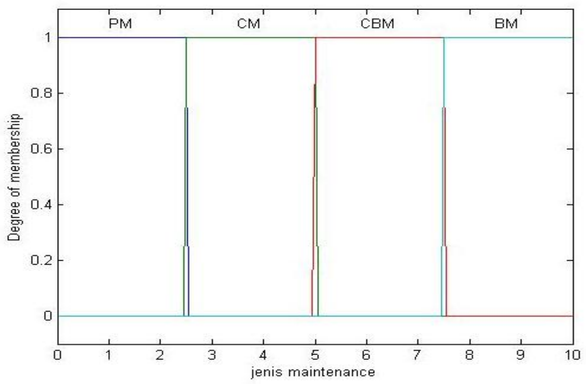

Figure 11. Membership function of maintenance type

The result of fuzzy logic RCM application in this company shows that preventive maintenance should be used for component that has high failure effect, while component with clear failure pattern should use condition based maintenance. Condition based maintenance and breakdown maintenance are suitable for component with clear failure symptom.

Conclusion

Fuzzy Logic RCM can be applied to help company to determined maintenance strategy which fit with current and future condition. Fuzzy logic gives degrees of truth for uncertain answer required by RCM.

Table 1. Result of fuzzy logic RCM

Mechine	Component	Effect	Pattern	Symptom	Maintenance	
Doubling	Automatic wire	2,325	4,5	4,675	3,75	CM
	Roll	2,325	9,35	5	6,25	CDM
	Gear	3	7,35	2,675	6,25	CDM
	Eyelet	2,325	4,5	4,825	3,75	CM
	Ear	2,325	4,5	4,825	3,75	CM
	Vanbelt	10	2,35	1,35	1,25	PM
Twisting	Wire	4,5	9,35	7,35	8,75	BM
	Yarn Guide	1,35	8,65	7,175	8,75	BM
	Handle	2,675	4,5	4,175	3,75	CM
	Pig tail	2,325	7,35	7,825	8,75	BM
	Tire	4,675	1,65	3,175	3,75	CM
	Tensor socket	2,325	7,35	1,175	6,25	CDM
Winding	Scissor	2	4,5	5	3,75	CM
	Vanbelt	10	2,35	1,35	1,25	PM
	Ceramic	2,325	7,35	7,325	8,75	BM
	Seal	10	2,175	1,325	1,25	PM

PM : Preventive Maintenance
CM : Corrective Maintenance
CDM : Condition Based Maintenance
BM : Breakdown Maintenance

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