FUZZY LOGIC BASED FAULT CLASIFICATION OF INDUCTION MOTOR BEARING USED IN HOME WATER PUMP SYSTEM

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FUZZY LOGIC BASED FAULT CLASIFICATION OF INDUCTION MOTOR BEARING USED IN HOME WATER PUMP SYSTEM

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ABSTRACT

The water pump is a device for moving the water from a lower pressure to a higher pressure or a lower place to a higher place. The use of the water pump is still a lot of obstacles such as it does not remove the water, short circuit in the winding, and bearing failure. This paper discusses the development of fault bearing classification of induction motor (IM) used in home water pump system using fuzzy logic model. It is difficult to classify fault bearing of IM using a mathematical model. Thus, a fuzzy logic classification is employed in this matter. This classification is divided into four conditions such as all bearing normal (N), front bearing fault (F), rear bearing fault (R), and both bearing fault (B). Whereas, the classification process consists of three stages such as taking fault data, features extraction, and fuzzy logic fault classification. The data of bearing fault is obtained from the current of the water pump IM taken using soundcard oscilloscope software. For further process these data are changed from time domain into frequency domain using Fast Fourier Transform (FFT) to aquire more fault signs during features extraction. In this stage, 4 features fault bearing data are extracted. In last stage, fuzzy logic model is used to select and clasify fault bearing of IM. The robustness of proposes fuzzy logic model is examined and results of clasification for four bearing fault condition are shown.

Keywords: *Home Water Pump System, Bearing Fault, Fuzzy Logic, Fast Fourier Transform.*

1. INTRODUCTION

Water pump is used to easily work human, especially move water from a lower pressure to a higher pressure or a lower place to a higher place. The use of water pump in home appliance is still a lot of obstacles such as it does not remove the water, short circuit in the winding, and bearing failure. The bearing is one part of the induction motor (IM) components. It has the important function to reduce the friction occur in shaft of IM, so that the rotor of IM can be rotated. The bearings must be built from strong material to allow the shaft and other engine elements to work properly. Several tests of bearing condition have been conducted and developed to detect the bearing fault of induction motor [1-4]. However, it requires a complex mathematical model and expensive fault detection devices [2,4,5].

In this paper, fault classification of induction motor bearing is developed using fuzzy logic model. Purpose of this classification is to know bearing fault types and early detection of bearing failure on home water pump system. The fault types consist of four conditions such as all bearing normal (N), front bearing fault (F), rear bearing fault (R), and both bearings fault (B). While, the classification process consists of three stages such as taking bearing fault data, features extraction, and fuzzy logic fault classification. First stage, the data of bearing fault is obtained from current of the water pump IM taken using soundcard oscilloscope software v.1.41 through audio line input of personal computer [6]. In second stage, these data obtained from first stage are converted from time domain into frequency domain using Fast Fourier Transform (FFT) to aquire more fault signs during features extraction stage and than 4 features fault bearing data are extracted. In last stage, fuzzy logic model is used to select and clasify fault bearing of IM. The effectiveness of proposes fuzzy logic model is clarified by simulation using MATLAB. The results of clasification for four bearing fault condition are shown and concluded.

2. RESEARCH METHODOLOGY

The research methodology used to classify bearing failure of induction motor is shown in Figure 1. The bearing fault data used in this paper is obtained from the current of induction motor employed in home water pump system. The fault types consist of four conditions such as all bearing normal (N), front bearing fault (F), rear bearing fault (R), and both bearings fault (B).

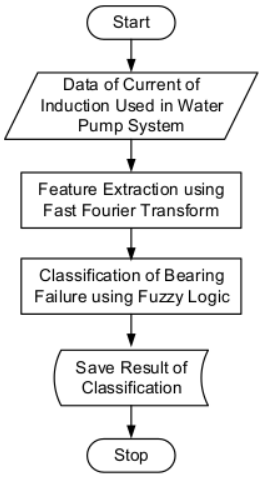

Figure 1. *Methodology to classify the bearing fault of induction motor*

In the feature extraction stage, bearing fault signal is converted from time domain to frequency domain using Fast Fourier Transform (FFT) to obtain more fault signals during features extraction and 4 features fault bearing data are extracted. Next stage, fuzzy logic model is used to select and clasify fault bearing of induction motor reffer to 4 bearing fault types.

2.1 Bearing of Induction Motor (IM)

Mechanical components of home water pump system are induction motor (IM), impeller, and foot valve. In the IM, the important mechanical component is bearing. Bearing is required to reduce friction at the shaft. Bearing fault can be caused over load, over heat, and corrosion [2,4]. Figure 2 show a bearing failure caused by corrosion.

Figure 2. *A Bearing fault caused by corrotion*

2.2 Fast Faurier Transform (FFT)

Frequency domain analysis used Fast Fourier Transform (FFT) method to convert from time domain into frequency domain. Frequency domain is used to show the frequency componets of a signal. Meanwhile, a time domain signal can be shown its time componets [1-3,6]. Formula of FFT for a signal *f(t)* can be expressed in Equation (1).

$$f(t) = \sum_{n=1}^{\infty} C_n \cos\left(n\omega t + \theta_n\right) \quad (1)$$

where c_n, $n\omega t$ and θ_n are magnitude of the nth component, frequency of the nth component, and phase angle of the nth component, respectively.

2.3 Fuzzy Logic Classification

Fuzzy logic is a system control method for problem solving which is suitable to be implemented into a system, from small systems to large and complex systems. This method can be employed to hardware, software, or a combination of both. In conventional logic, it states that everything is binary, meaning it has only two states, "yes or no", "1 or 0", and others. Therefore, the systems based on this logic have only a membership value of 0 or 1. Different on fuzzy logic control method, fuzzy logic control allows membership values to be between 0 and 1. This means that a situation may have two "Yes and No", "True and False" values, at the same time, but the value depends on the weight of the membership. Fuzzy logic control can be used in many fields [7-9] particularly classification and pattern matching of signals.

Block diagram of fuzzy logic control can be seen in Figure 3. Fuzzy logic control is built by fuzzification, inference mechanism, rule base, and defuzzification. Inference mechanism very depends on rule base of fuzzy logic. Fuzzy rule base are yielded through the knowledge of the process system [7-9]. In this paper, input signal of fuzzy logic control is current of induction motor and output signal of fuzzy logic control is bearing condition faults of induction motor used in home water pump system such as normal, front fault, rear fault, and both faults.

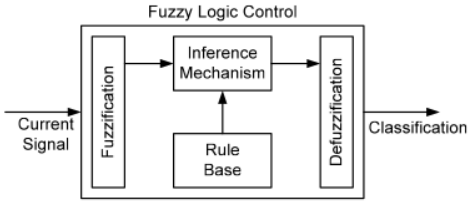

Figure 4. Block diagram of fuzzy logic control

2.4 Taking Data of Induction Motor Current

Taking data of induction motor current is shown in Figure 4. Taking data of induction motor (IM) current is conducted by connecting output current transformer (CT) to audio input of personal computer through probe oscilloscope circuit. Current of IM entered through line in audio of personal computer is read and stored using soundcard oscilloscope software version 1.41.

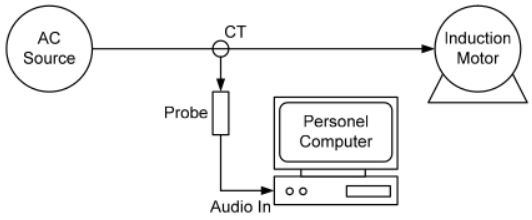

Figure 4. *Taking current data of IM.*

3. RESULT AND ANALISIS

Experimental setup of induction motor (IM) bearing fault classification used in home water pump system using fuzzy logic control is shown Figure 5. Furthermore, results of experiment setup are used to validate the fuzzy logic control model of IM bearing fault classification using SIMULINK-MATLAB. Parameters of IM are nominal voltage of 220 volts, frequency of 50 Hz, nominal power of 125 watts, total heat of 33 meters, suction head of 9 meters, and maximum capacity of 42 liter per minutes.

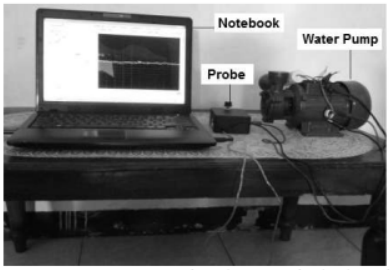

Figure 5. *Experiment setup of IM bearing fault classification*

3.1 Data of Induction Motor (IM) Current

Data of induction motor current is taken using soundcard oscilloscope software version 1.4 for bearing normal (N), front bearing fault (F), rear bearing fault (R), and both bearings fault (B). Figure 6, Figure 7, Figure 8 and Figure 9 show the current waveforms of IM for four bearing fault conditions.

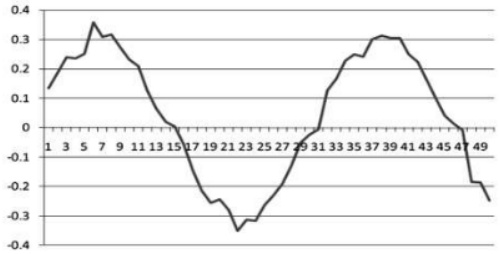

Figure 6. *Current waveform of IM for normal condition*

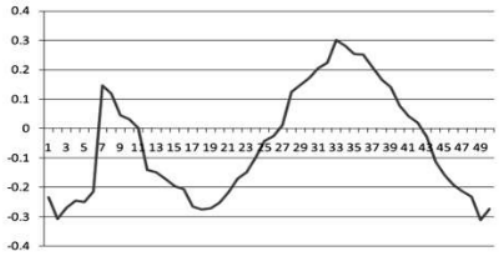

Figure 7. *Current waveform of IM for front bearing fault condition*

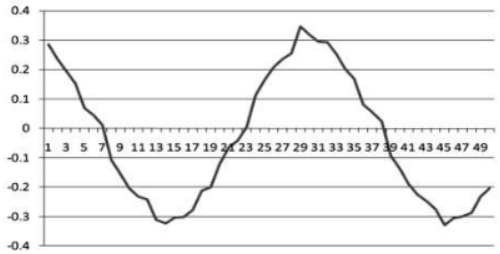

Figure 8. *Current waveform of IM for rear bearing fault condition*

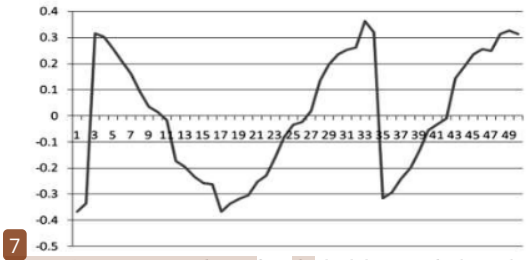

Figure 9. *Current waveform of IM for both bearing fault condition*

3.2 Features Extraction.

Features extraction of IM current waveform for 4 bearing fault conditions are done using Fast Fourier Transform (FFT). Feature extractions are based on Equation (1) and produce the magnitude of the n^{th} component FFT (C_n). Table 1 show the magnitude of the n^{th} component FFT (C_n) for each bearing fault condition.

Table 1. *Magnitude of the n^{th} component FFT (C_n)*

n^{th} component of FFT	Bearing condition			
	Normal (N)	Front fault (F)	Rear fault (R)	Both fault (B)
1	2.9528	0.1879	0.8783	1.8315
2	1.0375	1.9709	1.8326	1.34
3	0.2116	0.9284	0.7423	0.5156
4	0.2178	0.6013	0.633	0.197
5	0.0803	0.6013	0.3421	0.3817
6	0.024	0.3162	0.3545	0.2811
7	0.1609	0.3704	0.3241	0.0764
8	0.0564	0.254	0.308	0.1939
9	0.0564	0.254	0.308	0.1939
10	0.1609	0.3704	0.3241	0.0764

3.3 Classification of Bearing Fault using Fuzzy Logic Control

Fuzzy logic control (FLC) method used in bearing fault classification of IM is FIS SUGENO type. Design of FLC model for bearing fault classification has ten inputs and an output. Ten inputs represent 1^{st} – 10^{th} components of FFT (C_1 – C_{10}) from feature extraction process of induction motor current for each fault conditions. Whereas, an output of FLC is fault conditions of induction motor bearing. FLC model of bearing fault classification can be seen in Figure 10.

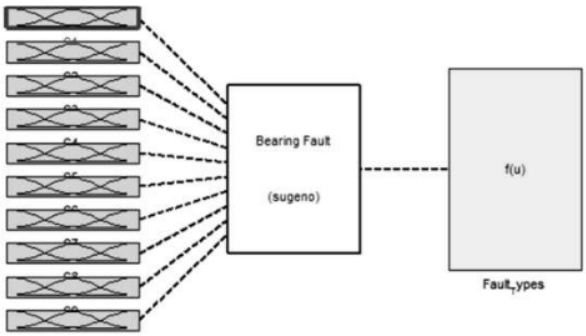

Figure 10. *FLC model for fault classification of induction motor bearing*

Each input of FLC model has 4 membership functions (MF). This membership functions describe 4 bearing fault conditions such as normal (N), front fault (F), rear fault (R), and both faults (B). Parameters of each membership functions base on the n^{th} component of FFT in feature extraction process. Figure 11 show 4 membership functions for first input (C_1).

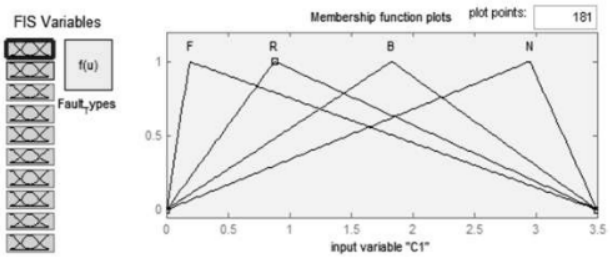

Figure 11. *Membership functions for first input (C_1)*

An output of FLC model also has 4 membership functions. Figure 12 express membership function for an output of FLC model. Whereas, the value of membership functions for a FLC output is shown in Table 2.

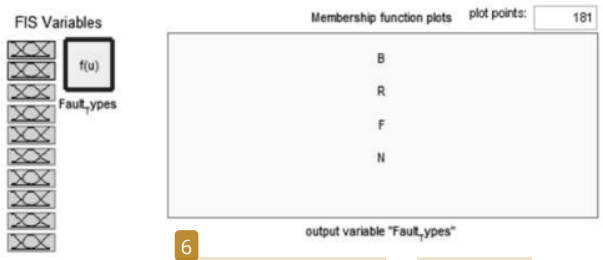

Figure 12. *Membership functions for an output of FLC*

Table 2. Value of membership functions for an output of FLC

Bearing Conditions	Values
Normal (N)	0
Front fault (F)	0.333
Rear fault (R)	0.666
Both fault (B)	1

The proposed FLC model is validated to indicate its performances. Its performances base on error value between design of FLC output and examination value of FLC output. Examination of FLC model is conducted using SIMULINK-MATLAB. Examination of FLC model using SIMULINK-MATLAB can be seen in Figure 13.

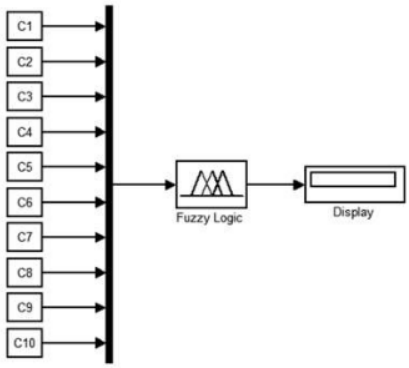

Figure 13. Examination of FLC model using SIMULINK-MATLAB

Examination results of proposed FLC model for each bearing fault condition are shown in Table 3. Examination results of proposed FLC model are compared with value of FLC output according to Table 2.

Examination results show that FLC model for IM bearing fault classification is successfully done, because error values of FLC model are less than 5%.

Table 3. *Result assessments of proposed FLC model*

Bearing Conditions	Values	Assessment
Normal (N)	0	0.047
Front fault (F)	0.333	0.349
Rear fault (R)	0.666	0.641
Both fault (B)	1	0.975

4. CONCLUSION

Fuzzy logic control (FLC) applied in fault classification of induction motor (IM) bearing has been presented and discussed. Fuzzy logic control (FLC) method is used to select and classify fault bearing of IM used in water pump system. The classification of bearing faults consist of four conditions such as normal (N), front bearing fault (F), rear bearing fault (R), and both bearings fault (B). The classification process is divided in three stages such as taking data of IM currents, features extractions, and fault classification using FLC model. The proposed FLC model is clarified to indicate its performances based on error values between design of FLC output and examination value of FLC output. Examination results show that FLC model is successfully conducted to classify the induction motor bearing fault which error values are less than 5%.

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