

Development of an Expert System on Failures of Hydraulic Cylinder using Fuzzy Logic

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ABSTRACT: Now a day mechanical component especially hydraulic system have become highly complex and sophisticated so that required approach/process should fulfill need of industries. Furthermore monitoring of hydraulic system difficult due to poor visibility in working area. So the method proposed here is a fuzzy logic approach which is a human reasoning ability to predict the output condition. The performance of hydraulic system is evaluated based on the membership functions and rule base extended by the fuzzy logic system. This paper presents an expert system that diagnosis the failure in hydraulic systems by simulating the reasoning of the expert, using fuzzy logic controller of Matlab. A graphical mapping step by step diagram was employed for the graphical representation of the output of a hydraulic system including piston movement, noise and leakage. The fuzzy logic modelling technique employed here can be used for online prediction of the performance of hydraulic system without inspecting the operation area. More importantly, simulation results confirm how fuzzy logic is advantageous over the conventional method by being more informative regarding the output condition.

KEYWORDS:Hydraulic System, Fuzzy Logic, Expert System, Matlab.

I. INTRODUCTION

Hydraulic system can contribute greatly to the reasonable production of various machines and modernization of equipment. Reliable operation of a hydraulic system can only be ensured through proper design, effective maintenance and continuous monitoring. Each of these areas needs the expertise of well-trained and experienced individuals. So this paper develops an expert system model using fuzzy logic for failure analysis of hydraulic system.

1. HYDRAULIC SYSTEM

In heavy industrial equipment, power transfer is primarily provided by a hydraulic system. Hydraulic systems, in recent years, have played an important role in production technology because of their ability to drive and control heavy loads in combination with high speed. Increasing production rates and degrees of automation demand higher performance and reliability from the production machines necessarily required. In addition to the reliability of hydraulic system, the hydraulic system fault detection and diagnosis preferable and in a superior way importance as the development of technology. Like any other system hydraulic systems are of a mind to diverse types of faults. A fault can be defined as deviation from the normal or expected [8]. Faults can be categorized into two types: Foremost, partial fault failure wherever the system will still operate though there's a tiny low quantity of fault and second total fault failure where the system needs to be shut down.

2. EXPERT SYSTEM

Expert systems offer a useful tool for a range of situations like designing complicated hydraulic systems or fault detection in hydraulic driven machines, especially in cases where hydraulic systems are large and complicated, fast fault detection is important or specialists are not available [1]. Existing expert system has a high percentage agreement by whole of experts in a particular field in many situations. Expert system determines the defective element of system, degree of wear, right time for replacement. Expert system applications in this domain have been developed by Burton & Sargent [3] and Nakashima & Baba [9], for design, installation and maintenance of hydraulic components or systems. In the expert problem solving situations, two different kinds of knowledge may be employed. These types have been referred to as shallow or low road knowledge and deep or high road knowledge. Shallow knowledge consists of rules-of-thumb, often in the form of condition-action pairs that have been acquired by the expert through first-hand experience in the field or from a more experienced expert. Deep knowledge, on the other hand, provides the lower level, causal, functional, and physical information in a problem solving situation [4].

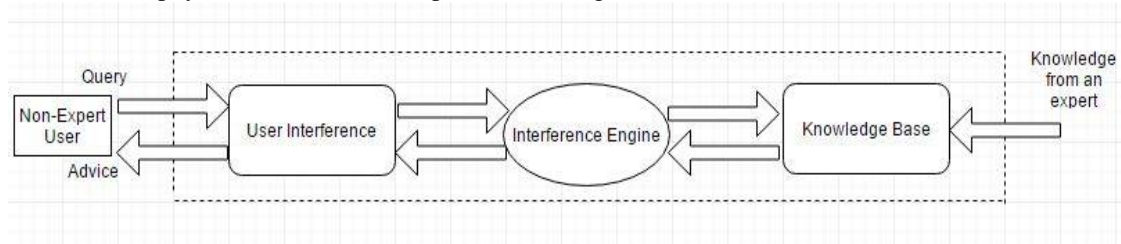


Figure 1 Working principle of expert system

An Expert system made of three parts

1. User Interference - This is the system that permits a non-expert user to query the expert system, and to receive advice. The user-interference is intended to be straightforward to use as attainable.
2. A Knowledge Base - This is often a set of facts and rules. The knowledge basis created from information provided by human experts the knowledge base is individualistic from generally told other components of an expert system which makes it flexible to accept changes without provocative the any system.
3. An inference engine - This acts rather like a search engine, examining the content for info that matches the user's query. The inference engine uses the query to look the knowledge domain then provides a solution or some advice to the user.

The fault detection of hydraulic system is to be solved by developing an expert system using a fuzzy logic of MATLAB [15]. Other approach like Wald's Sequential Test, as in Khan et al. [7] which is a conventional approach or using innovative approaches like genetic algorithms as in Xuewu et al. [17], neural networks as in Qian-jin et al. [12], Shing et al. [14] etc. each having its own advantages and disadvantages.

3. FUZZY LOGIC

Fuzzy control has found several applications in an exceedingly kind of fields since Prof. Zadeh [18] introduced fuzzy set theory in 1965. Among the foremost flourishing applications of this theory has been the area of fuzzy logic controller (FLC) initiated by the work of Mamdani and Assilian [13]. FLC has the advantage that it doesn't need an accurate mathematical model of the process. It uses a collection of artificial rules in a decision-making table and calculates an output supported the table. Input variables undergo the fuzzification interface and are converted to linguistic variables. Then, an info and rule base holding the decision- making logic are used to infer the fuzzy output. Finally, a defuzzification method converts the fuzzy output into a signal to be sent out [11]. Fuzzy logic has several advantages like less modeling difficulty and exemption to interpret human reasoning using linguistic variables. This makes it doable to require into consideration the uncertainties and nonlinearities otherwise terribly tough to model mathematically.

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II. RELATED WORK

An expert system design known as the integrated diagnostic model (IDM) is design that integrates two sources of knowledge, a shallow, reasoning oriented, experimental knowledge base and deep, functionally oriented, physical knowledge base. The experiential knowledge base offers a framework for structuring the shallow knowledge for diagnostic problem solving while the physical knowledge base is capable of representing many different dynamic systems, especially in the electrical and mechanical domains [4]. Accurately identify the fault position and the reason for failure and make repairs, allowing the system returned to normal operation [6]. The traditional method of diagnosis of the hydraulic system failure is a logical analysis method of successive approximation. So the use of fuzzy logic make decision like whether 'a fault has occurred or not?' is upgraded to 'what is the severity of that fault?' at the output [8]. The fuzzy logic controller is able to overcome the nonlinearities and uncertainties within the system [16]. The fuzzy clustering technique used was found to be adequate for establishing the relationship between the input process parameters and the outputs [10]. The dynamic properties of hydraulic differential cylinder obtained by simulation with the simulation software MATLAB-Simulink [5].

III. EXPERIMENTAL DETAIL

Present research study consider hydraulic cylinder for the fuzzy logic model development on matlab. The hydraulic cylinder represents a cost effective and simply constructed linear drive. The performance of the hydraulic cylinder is selected based on three input and three output parameters. The practical operating values have taken from the manufacture catalogue of CE-type hydraulic cylinder.

To fulfil research objective, specification of CE-type of hydraulic cylinder given below as:

- Cylinder Bore -150 mm
- Operating pressure - (3-140) Kgf/Cm²
- Flow rate - (0.18 - 5.3) Cm³/sec
- Operating Temperature - (-10 °C - 80 °C)

IV. DESIGN OF FUZZY LOGIC CONTROLLER

1. Input and their membership function (Fuzzy Sets)

a. Operating Pressure

Operating pressure range of CE-type hydraulic cylinder is 3-140 kgf/cm². The operating pressure is mostly affects the output by showing movement of piston no, slow or free depends upon the pressure applied on the piston. The case of no movement happens at the stage that the pressure is too low to move the piston mass. Similarly free movement happens when the pressure is too high. The condition slow movement is the middle range of the operating pressure range. The first input operating pressure is divided into 3 membership functions namely low, medium and high as shown in below figure 2

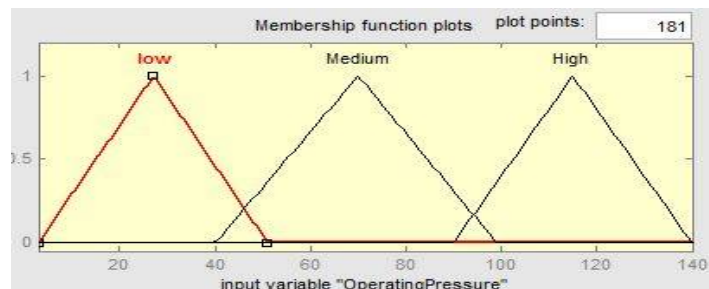


Figure 2 Membership function of operating pressure

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b. Flow Rate

It is consistent to mind that in a hydraulic system, flow determines actuator speed and response. Therefore, a loss of speed indicates a loss of flow. Flow can escape from a hydraulic circuit through leakage. The second input flow rate is divided into 3 membership functions ranging between 0.18 – 5.3 cm³/sec namely low, medium and high as shown in figure 3

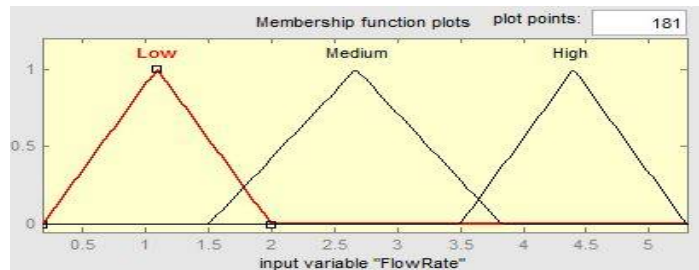


Figure 3 Membership function of flow rate

c. Operating Temperature

High operating temperature can damage seals and accelerate degradation of the fluid. This means that the operation of any hydraulic system at high temperature is detrimental and should be avoided. Fluid temperature is too high when viscosity falls below the optimum value for the system components. High fluid temperature can be caused by anything that either reduces the system’s capability to dissipate heat or will increase its heat load. The third input operating temperature ranging –10°C - 80°C is divided into 3 membership functions namely low, medium and high as shown in figure 4

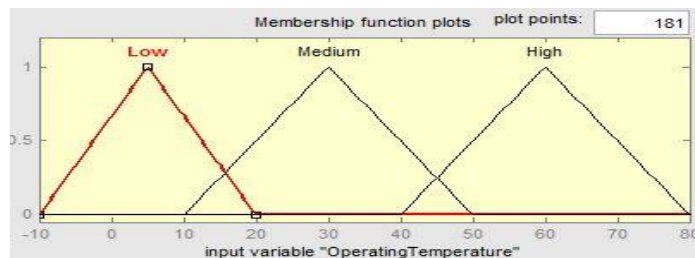


Figure 4 Membership function of operating temperature

2. Output and their membership functions (Fuzzy Sets)

a. Piston Movement

The first and main output parameters of hydraulic system is the piston movement. This movement of the piston is categories into three i.e. no, slow and free movement. This movement of the system is depend upon the input parameter as provided above. So for the piston movement membership function are as shown in figure 5

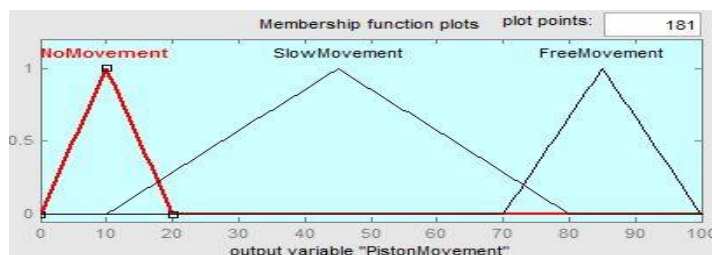


Figure 5 Membership function of piston movement

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b. Noise

Abnormal noise in hydraulic systems is the second output from hydraulic cylinder. This output result from the abnormality in the input parameter such as low pressure and low flow rate etc. The noise can judge at the output by either present or absent, so the membership function for the noise as shown in figure 6

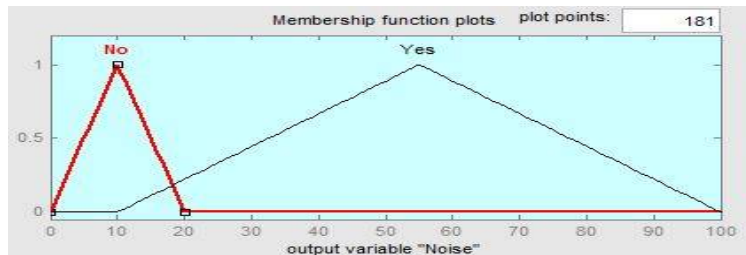


Figure 6 Membership Function for noise

c. Leakage

Based on the input parameters the leakage cause such as high operating temperature. When the fluid temperature too high the viscosity of the fluid is lowered and also there is chances to damage the seal. So the low viscous fluid passes through the damage seal. Where there is leakage there is a pressure drop, and where there is a pressure drop heat is generated. The influence of leakage on heat load means that slow operation and high fluid temperature often appear together. The Leakage can judge at the output by either present or absent, so the membership function for the Leakage as shown in figure 7

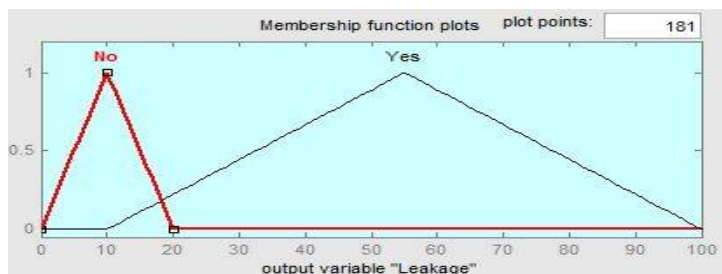


Figure 7 Membership function for leakage

V. FUZZY MODEL CONSTRUCTION

The output of hydraulic cylinder is dependent on several parameters which can be varying over a wide range. Fuzzy logic is a highly flexible and nonlinear modelling technique with an ability to learn the relationship between inputs variables and output features. The most successful applications of fuzzy set theory is observed in modeling the experimental data involving certain uncertainties between the relationships of input process variables and responses [2]. Its major features are the use of linguistic variables instead of numerical variables. Linguistic variables are defined as the variables whose values are sentences in natural language (such as low, medium and high) and can be represented by fuzzy sets. Fuzzy sets are characterized by fuzzification, membership functions, a fuzzy rule, an inference system and a defuzzification inference. The structure of three inputs, three outputs fuzzy logic controller developed for this present research is shown in figure 8

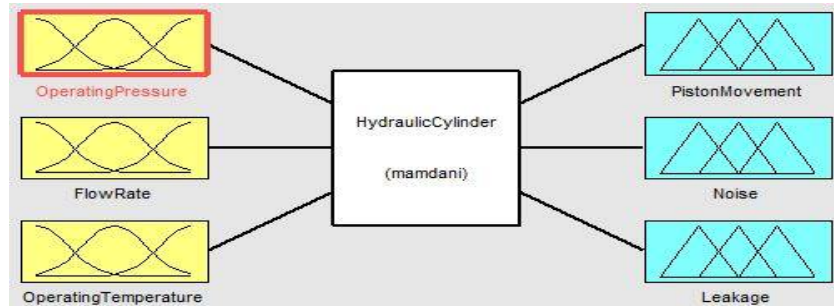


Figure 8 Input-output parameters of Fuzzy logic control model

The fuzzy rules are expressed in the form of fuzzy conditional statements.

“If x is small and y is large THEN z is large”

Where x and y are fuzzy variables, and small and large are labels of fuzzy set.

A fuzzy logic controller is based on a collection of control rules. The execution of these rules is governed by the compositional rule. In this study the triangular membership functions were used for the input process parameters such as operating pressure, flow rate and operating temperature to predict output of the hydraulic cylinder operation. The membership function for each inputs and outputs variables were divided into different levels such as low, medium and high or yes or no. This base comprised of groups of rules. Hence total numbers of rules for the three outputs such as piston movement, noise and leakage is 81 rules (Table 1).

Table 1 - Fuzzy rules for hydraulic cylinder

S. N.	Fuzzy Rules
1.	IF Operating pressure is low AND flow rate is low AND operating temperature is low THEN piston movement is no movement
2.	IF operating pressure is low AND flow rate is low AND operating temperature is low THEN noise is yes
3.	IF operating pressure is low AND flow rate is low AND operating temperature is low THEN leakage is no
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-	
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79.	IF operating pressure is high AND flow rate is high AND operating temperature is high THEN piston movement is free movement
80.	IF operating pressure is high AND flow rate is high AND operating temperature is high THEN noise produced is no
81.	IF operating pressure is high AND flow rate is high AND operating temperature is high THEN leakage is yes

VI. RESULTS: RULE VIEWER

Rule view opens the Rule Viewer for the fuzzy inference system. It is used to view the entire implication process from beginning to end. It can move around the line indices that correspond to the inputs and then monitor the system readjust and compute the new output. The rules can also be seen from the rule viewer using the fuzzy logic toolbox in MATLAB software as shown in below figure 9 & 10

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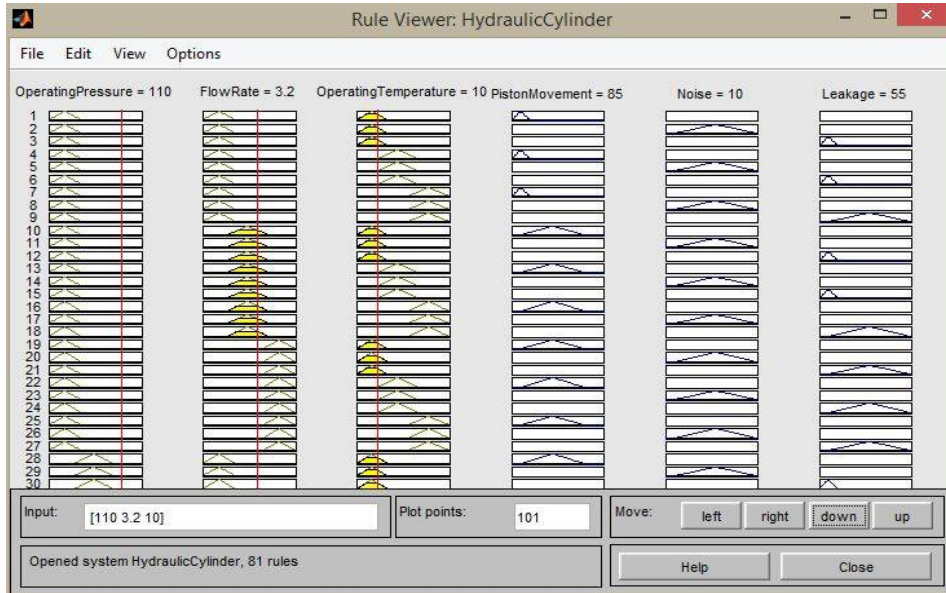


Figure 9 Test result from fuzzy logic for free piston movement

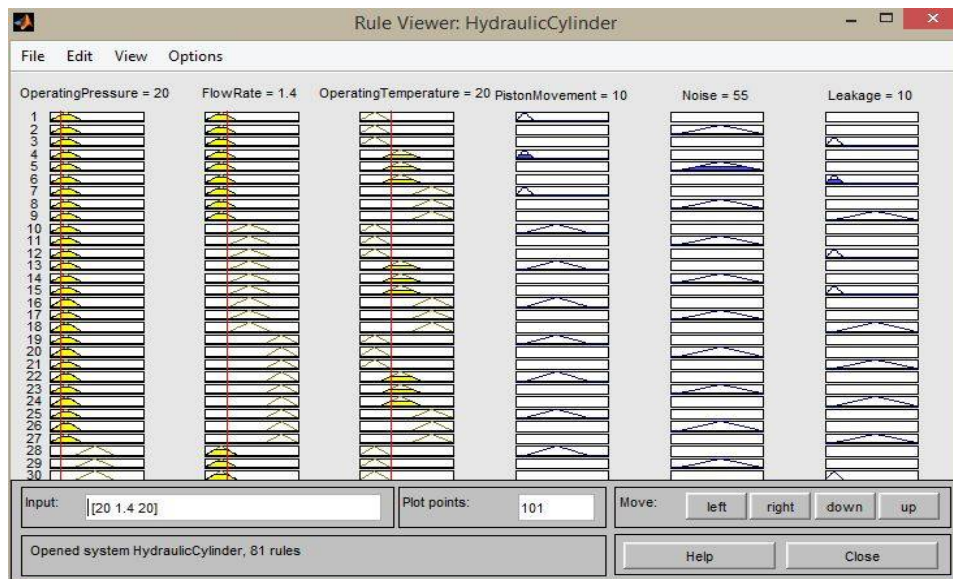


Figure 10 Test result from fuzzy logic for no piston movement

VII. SIMULATION

A MATLAB Simulink model was developed to predict the performance of hydraulic cylinder at different variable condition. This simulation has carried out in MATLAB SIMULINK using fuzzy logic controller as shown in figure 11. Simulation model developed by fuzzy logic controller of MATLAB is act as expert system for hydraulic cylinder. As putting the value of input variable value we are getting the value of the output. If we install this system on the hydraulic system we get the output value at the any stage of manufacturing operation by simply putting the input value.

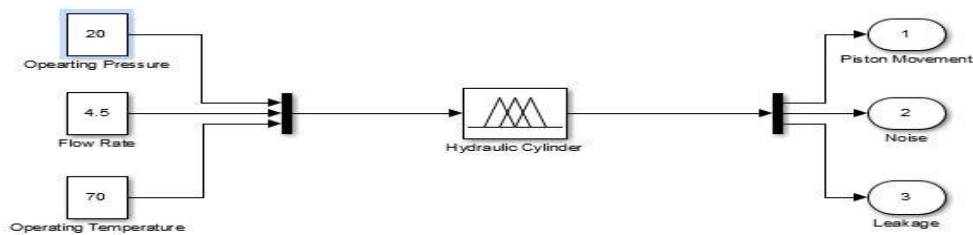


Figure 11 MATLAB/SIMULINK mode

VII. CONCLUSION

The main objective of this research study is to provide the actual operating information about the systems health which would guide to make decisions about the output of the system. This information is used to avoid any serious damage to the system. Fuzzy logic is a good simulation because there is no optimized mathematical model available which describes the output condition based on the available inputs. The simulation of fuzzy logic model act as an expert system for hydraulic system. The observed knowledge is directly used for fault detection process instead of any detailed modeling. Fuzzy logic acts as a good extension to upgrade the system.

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