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DEVELOPMENT OF AN EXPERT SYSTEM FOR DIAGNOSIS OF BEARING FAULTS OF ROTATING MACHINERY WITH A CASE STUDY ON BOILER FEED PUMP

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ABSTRACT

In this paper an attempt has been made to develop an expert system called VIBMASTER to help the plant maintenance persons in diagnosing the cause of excessive vibration at the bearing supports of a rotating machinery. In the expert system a data base has been compiled from Standards, Journals, Handbooks and Rules from Maintenance Manuals related to maintenance engineering and management. The transfer of knowledge from these sources into the expert system for diagnosis is achieved with knowledge engineering procedures using if and then rules. The developed software tool can identify the fault(s) using vibration characteristics like velocity, speed of machine and signatures. The proposed system has been developed on Microsoft Windows environment and is written in Microsoft Visual Basic and Visual C++. To validate, the expert system is tested with the data collected at the bearing supports of a Boiler Feed Pump of a Boiler Feed Pump train of a large utility thermal power plant.

Keywords: Expert System, Fault Diagnosis, Boiler Feed Pump Train.

INTRODUCTION

Condition monitoring is a technique which enables the maintenance engineer to detect the incipient failure with ease and confidence in advance. Out of the number of condition monitoring techniques available, Vibration based monitoring is the best and early indicator of a machine's health [1, 2, 3]. Diagnostic process is a process of locating the exact cause(s) for fault or failure. Since a machine has many components and is highly complex, diagnosis of a machine fault usually requires technical skill and experience. It also requires extensive understanding of the machine's structure, operation and general concepts of diagnosis. This requires an expert engineer to have a domain specific knowledge of maintenance and knows the 'ins and outs' of the system. In normal situation, the expert is either too busy with some other tasks or a specific component expert is not available at all or the expert left the organization [4].

It is necessary to develop an expert system to carry out the diagnosis process with the help of a non-expert. In the recent past, various approaches have been used to produce expert systems. Among them, the rule-based diagnostic expert system is the most promising [5, 6, 7]. To guide the diagnosis, expert systems rely on an inference engine to derive the conclusions from the knowledge base. The inference engine checks all heuristic rules in the knowledge base based on backward chaining, forward chaining,

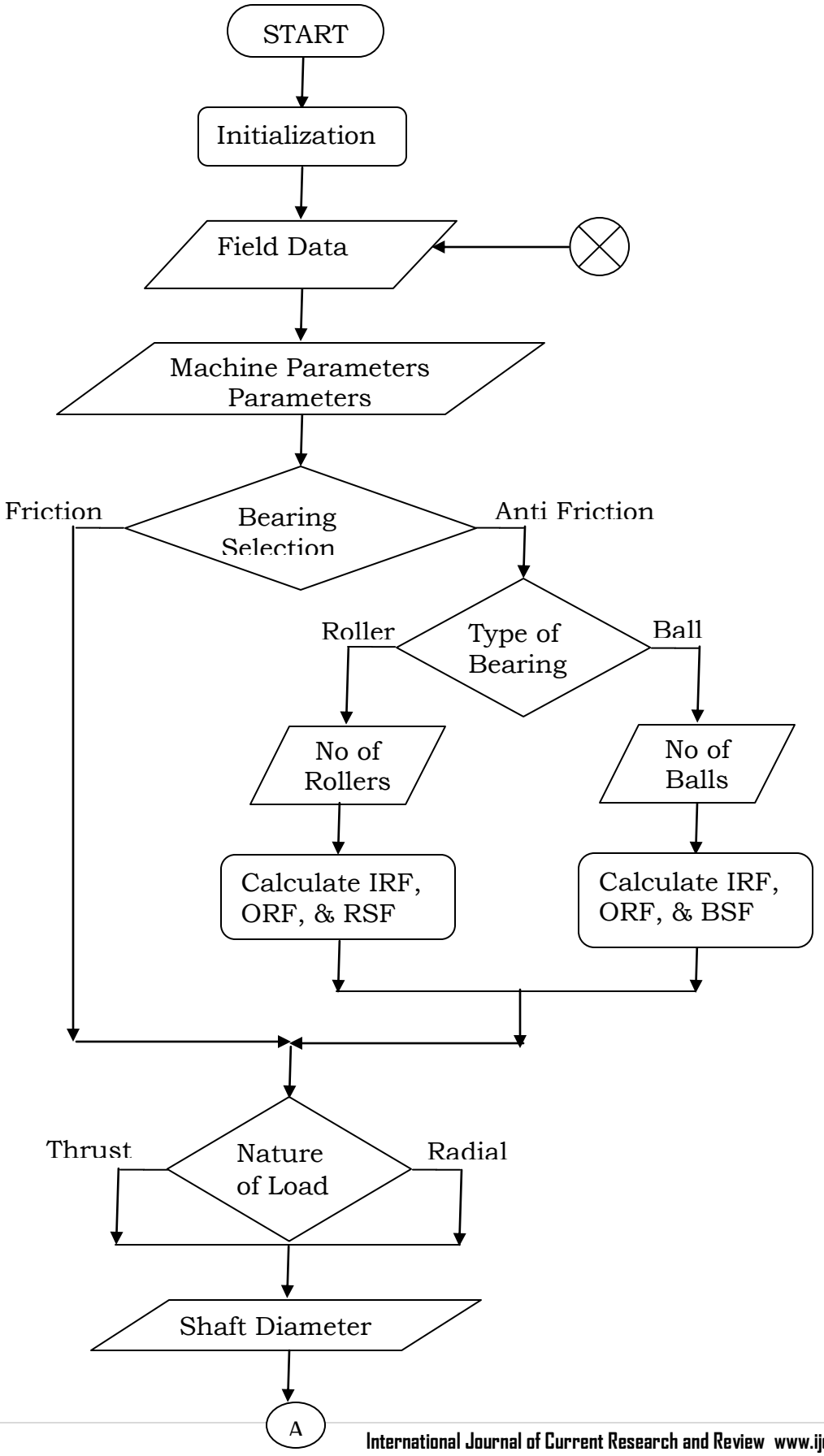
or mixed modes of chaining. If the inference engine finds that any premise clause is unknown during the rule-checking process, the inference engine generates a query to ask the user. For improving search efficiency, Vranes et al [9] proposed a best-first search strategy based on fault probability information. The nodes with high fault probability components are generated and checked first, followed by those with lower fault probability. However, fault probability information is not the only criterion to determine the priority of each node. The other criteria such as the difficulty of fault diagnosis and the symptoms should be considered. Liu and Liu [8] proposed a new search strategy to enhance the efficiency of the diagnostic process for air compressor troubleshooting. A diagnostic tree is constructed based on the functions and connectivity of the air compressor devices. A fuzzy multiple attribute decision making method for a single user is used to determine the priority of each node in the tree. Then, the priorities of devices control the diagnostic process. However, the expert system for air compressor troubleshooting lacks generality. In addition, there might be more than one fault diagnosis expert and they may have different opinions about the importance of each criterion. Hence, a fuzzy group multiple attribute decision making method seems more appropriate for this problem [10, 11]. An efficient Expert System for Machine Fault Diagnosis (EMFDES) has been developed via a fuzzy group multiple attribute decision making method to overcome the diagnosis inefficiency problem, mentioned above. EMFDES is a hybrid expert system that combines an expert system and a fuzzy group multiple attribute decision making [12] method.

Reddy CM[13] mentioned about the use of advanced techniques such as Artificial Intelligence. He further stated that these techniques provide a range of tools that allow successful condition monitoring and fault diagnosis systems to build and deploy efficiently. Gale KW and Walton J[14] described the evaluation of an expert system for condition monitoring of hydraulic control systems in hot steel strip finishing mill. The system integrates real time LABVIEW data acquisition with GENSEM G2 expert system running on windows. MISHRA.C and Muncherji.S [15] discussed about an expert system development at Tata steel, Jamshedpur for wear debris analysis. The system guides analyst through a step by step procedure and records all observations regarding presence of different types of wear particles. The system also offers the diagnostic and corrective actions. Depold HR and Gass FD [16] depicted the application of expert systems for gas turbine. These systems integrate data, furnish diagnosis, provide prognosis for planning maintenance action.

METHODOLOGY

In the present work Data files are created, based on data bank, giving emphasis to vibrational velocity, to tag the offensive vibration source. The domain is established by incorporating Codes and Standards as per ISO–2372, stipulating the limiting velocity for trouble free operation based on RPM of rotor which is supported by bearings.

The source code is developed in C++ with #.net as back up for graphic visualization. Fig.1 gives the Flow Chart.


START
Initialization
Field Data
Machine Parameters
Parameters
Friction
Bearing
Selection
Anti Friction
Roller
Type of
Bearing
Ball
No of
Rollers
No of
Balls
Calculate IRF,
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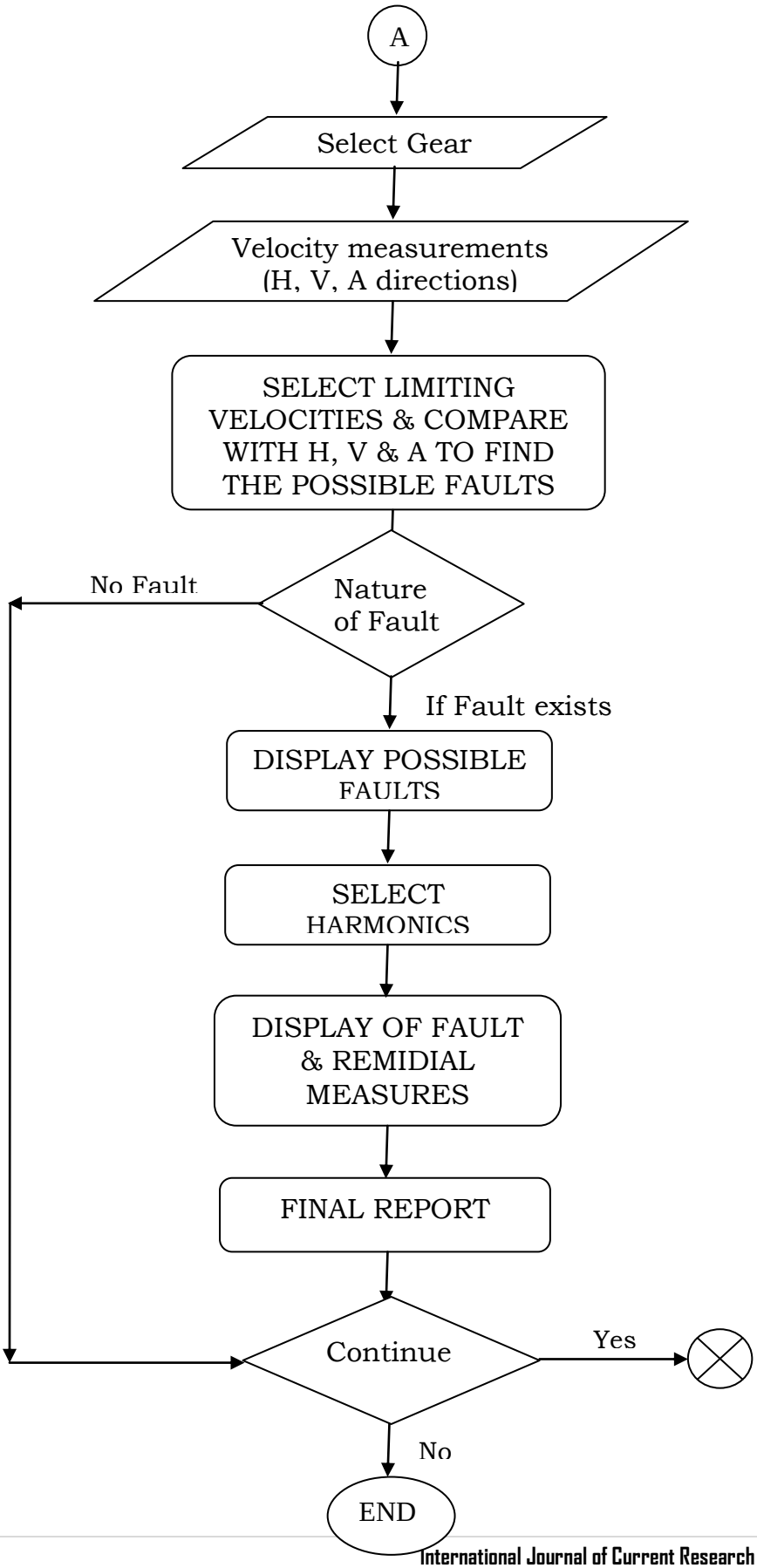
Calculate IRF,
ORF, & BSF
Thrust
Nature
of Load
Radial
Shaft Diameter
A


A
Select Gear
Velocity measurements
(H, V, A directions)
SELECT LIMITING
VELOCITIES & COMPARE
WITH H, V & A TO FIND
THE POSSIBLE FAULTS
Nature
of Fault
No Fault
If Fault exists
DISPLAY POSSIBLE
FAULTS
SELECT
HARMONICS
DISPLAY OF FAULT
& REMIDIAL
MEASURES
FINAL REPORT
Continue
Yes
No
END

The following templates are designed as primary data to be given as input to the expert system.

1. Field data collection
2. Machine parameters
3. Tri-axial Measurements
4. Harmonics of peaks

The expert system facilitates the following

- Bearing fault diagnosis in terms of tri axial measurements
- Bearing fault diagnosis in terms of signature analysis
- Vibration trouble shooting guide lines for bearings.
- Probable causes of faults and the remedial measures to be taken up

The expert system facilitates the identification of existing fault with ease by simply giving velocity measurements along vertical, horizontal and axial directions along with harmonics of speeds at which peaks are observed, as input.

The proposed system also suggests the remedial measures to bring down the intensity of offensive vibration to ensure trouble free operation. Options are provided to select a particular type of bearing and / or gear to diagnose the fault specifically.

Case Study

Fig. 2 shows the line diagram of a Boiler Feed Pump train under investigation. It is supported by 10 journal bearings. The motor drives the Booster Pump which runs at a speed of 1440rpm. The Boiler Feed pump (BFP) is run by the output shaft of a gear coupling. The speed of BFP shaft is 5220rpm. It is proposed to validate the expert system by measuring vibration intensity at the key point 9 and 10, related to BFP. Table 1 shows the recorded values at these key points in the month of June, 2011.

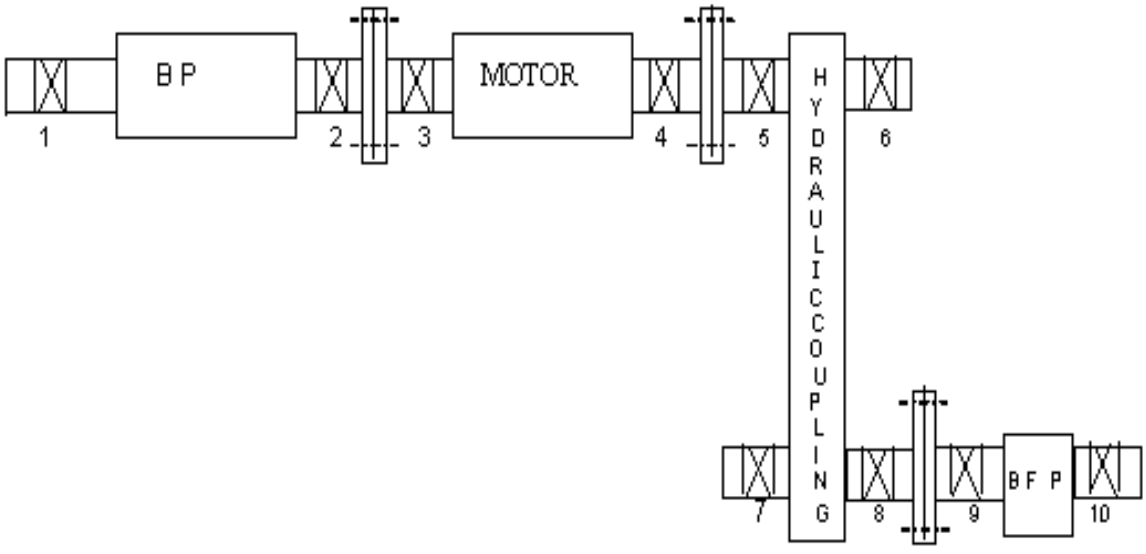


Fig.2 Boiler Feed Pump train with key points.

Table 1. Overall Vibration Levels

Key point	Direction	Velocity (mm/sec)
9	Horizontal	7.33
	Vertical	4.15
	Axial	7.13
10	**Horizontal**	**9.07**
	Vertical	5.95
	Axial	**13.6**

Fig.3 shows the vibration signature at Bearing 10 in the Horizontal direction. The Velocity amplitude is high along horizontal for the BFP non – driving end. The predominant frequency is at 5X.

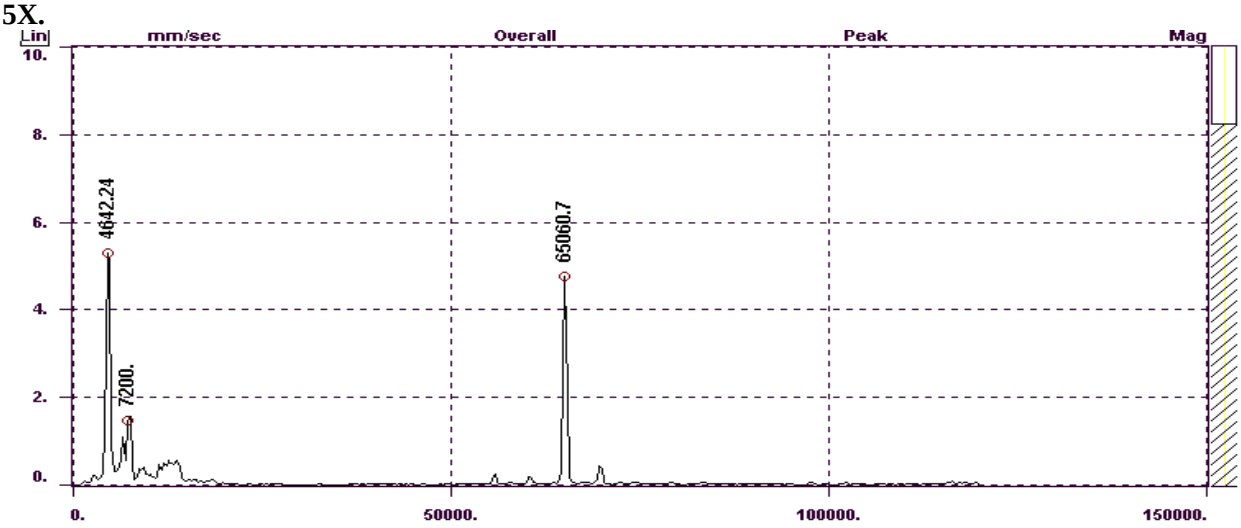


Fig. 3 Vibration spectrum at Bearing 10 in Horizontal direction

Application of Expert System

In the developed expert system, "VIBMASTER", the velocity values are given at the appropriate screen. Figs. 4 and 5 shows the Input and Out Put screens. From Fig 5 it is clearly evident that the fault is due to soft footing. The remedial measures suggested are to check for distortion of base frame or deterioration of grouting giving raise to soft footing. After proper reinforcement of the base the subsequent measurement indicated a velocity of 7.20mm/sec, at bearing 10 along horizontal direction. At bearing 9 the vibration velocity is well within the limit along 3 directions. The velocity intensity is exceeding the limiting value along horizontal direction at bearing 10 and the reason can be attributed to soft footing [17].

Fig.4 Input Values at Bearing 10

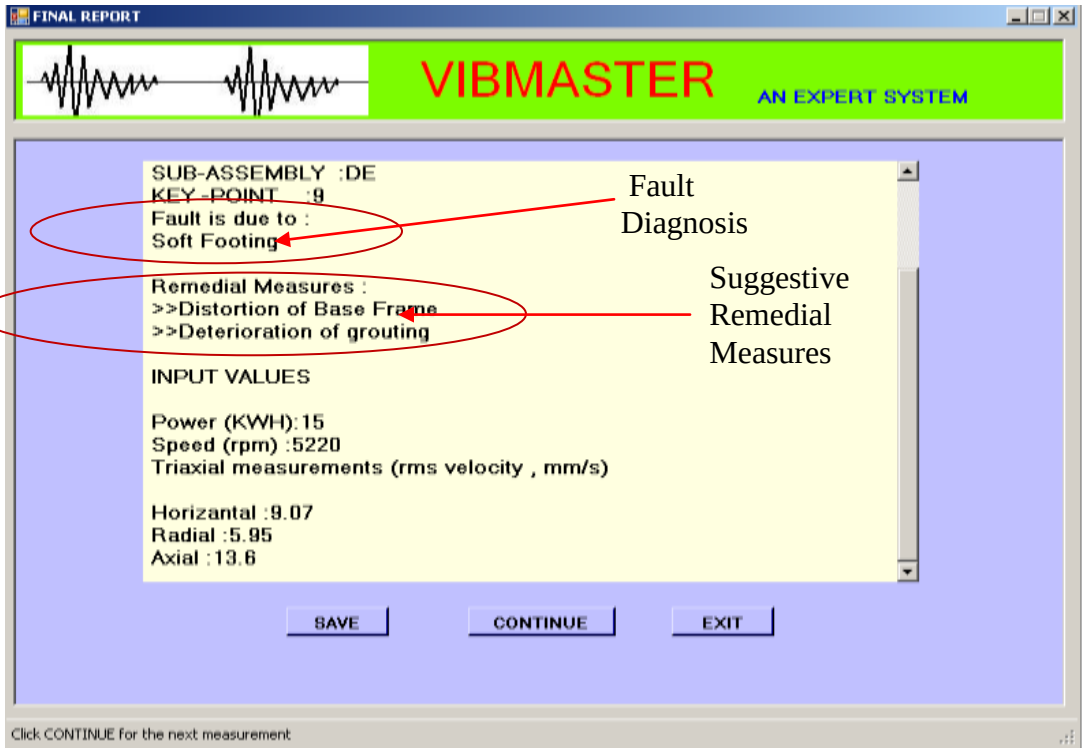


Fig. 5 Fault diagnosis and remedial measures at Bearing 10

CONCLUSIONS

This paper describes the development of a vibration based expert system, VIBMASTER, which enables operators of rotating machinery, to solve vibration problems. The developed expert system validated with experimental data taken at the bearings of BFP of a large utility thermal power palnt. The expert system is used to provide the information possible to avoid or reduce the vibration intensity in the absence of expert. It is suitable to monitor and diagnose 18 different probable faults in any rotating machinery. The proposed expert system is developed to diagnose and suggest the remedial measures for rotating machinery.

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