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Fuzzy Modeling to Calculate Component Failure Criticality Index for Forging Industry

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Abstract: *The aim of the thesis is to develop a hybrid neuro fuzzy based decision making model which helps the production personnel to go for preventive action before failure occurs. This model gives fuzzy risk priority number as an output, on basis of which a failure priority ranking is to be decided, which is to implemented for making the system more reliable and helps to maintain continuous production without rework and rejection in a plant.*

The methodology uses expert's experience and expert's judgment in terms of input linguistic variable which helps in formation of fuzzy rules on the basis of which the output crisp number is generated. An adaptive neuro inference system is incorporated for generating rule base and assigning membership function and values to the input linguistic variables.

A case study is conducted in one of the forging industry in Punjab, from where a data regarding the various failures and their potential causes was collected corresponding to various input parameters which considers various aspects. On the basis of judgment and experience of engineers and other maintenance personals a rule base was generated which gives a unique fuzzy risk priority number corresponding to each failure. Corresponding to this fuzzy risk priority number,failure priority ranking is prepared which helps the production personnel to take corrective action for preventing each failure and continuous running of production.

Introduction:

In the present era, there has been tremendous pressure on manufacturing and service organizations to remain competitive and provide timely delivery of quality products. The managers and engineers have been forced to optimize the performance of all systems involved in their organizations. The deterioration and failure of these systems might incur high costs due to production losses and delays, unplanned intervention on the system and safety hazards. But it is not the case. Failure is an unavoidable phenomenon associated with the technological products and systems. Overtime, however, a given system suffers failures and has to bring back to the serviceable state through appropriate maintenance and repairs. The causes of failure may be human error, poor maintenance, inadequate testing, inspection or improper use and the resulting effects vary from minor in convenience to lost service time and sometimes to loss of material, equipment's and even life. The disastrous consequences of unreliable behavior of such equipment's and systems have led to desire of high reliability. The performance of a system may be enhanced through a proper design optimization at the design stage and by actively maintaining the same during its service life. Proper planning and scheduling plays a prominent role in reducing production costs, increasing availability of manufacturing systems and improving quality and productivity by making failure free system.

The definition of failure is the inability of a system or product to meet the required function. Failure can be dramatic and sudden or subtle and gradual resulting in the system or product degradation. Defective customer products from common household appliances to the much publicized automotive recall have impacted from a few to millions of individual. Not only product failure but even breakdown in the service are potentially damaging. A misdiagnosed patient in a hospital as a result of a communication failure can be harmful to the patient and to the reputation to the hospital itself.

With increasing technological sophistication, the problem of finding and correcting failures is becoming more complex. The need for "first past manufacturing ", in which a product or service has been made failure free prior to implementation is critical.

The decision for the best recommended action is not an easy task for maintenance managers. A good maintenance program must define maintenance strategies for different facilities, i.e., it must combine technical requirements with the management strategy. The failure mode of every component must be studied in order to assess the best solution for failure, in accordance with its failure pattern, impact and cost on the whole system.

This information helps the production and maintenance personnel to decide the best action and to assign the different priorities to various processes in a plant. The management of large number of tangible and intangible attributes that must be taken into account represents the complexity of the problem. To enhance the system reliability and for continuous running of production plants, an equipment or their components must be prioritized on the basis of various failures and their mode of failure. Further depending upon the different priority ranging from highest and lowest the failure priority policy is to be decided i.e whether the preventive maintenance, condition monitoring or monitoring schedules are required for the given system to avoid failures and enhance the system reliability. Failure modes are generally prioritized using failure mode effect analysis technique which calculates risk priority number as discussed below.

Failure mode effect analysis:

Failure mode and effect analysis is a structured, bottom-up approach that starts with known potential failure modes at one level and investigates the effect on the next subsystem level. All complex mechanical systems are composed of several subsystems which can be further broken down up to a component level (Wang *et al.*, 1996). FMEA as a formal design methodology was developed at Grumman Aircraft Corporation in the 1950 and 60s (Coutinho, 1964) and was applied to naval aircraft flight control systems. Since then, it has been extensively used as a powerful tool for safety and reliability analysis of products and processes in a wide range of industries particularly, aerospace, nuclear and automotive industries (Gilchrist 1993, Connor 2001, Eblieng 2000). In 1977, it was adopted and promoted by Ford Motor Company. The Ford procedure extended FMEA methodology in automotive sector to assess and prioritize potential process and design- related failures.

FMEA is a widely-used quality improvement and risk assessment tool in manufacturing industry. This method combines the human knowledge and experience to identify known or potential failure modes of a product or process. By evaluating the failures of a product or process and their effects, FMEA team could initiate corrective actions or preventive measures as soon as possible to eliminate or reduce the chance of the failures occurring. Shortly speaking, FMEA is a useful technique to identify: (1) the potential failure modes of a product or process, (2) the effects of these failures, and (3) the criticality of these failure effects in the performance of a product or process. In FMEA method, three parameters (severity, occurrence, and detection) are used to describe each failure mode of a product or process. Severity is the seriousness of the failure. Occurrence is the probability or frequency of the failure occurring. Detection is the likelihood of detecting the failure. Each parameter can be assigned a rating from 1 to 10. Risk priority number (RPN) is the product of the severity, occurrence, and detection ratings. And, the criticality of each failure mode can be generated by the calculation of RPN. The failure having a higher RPN will have a higher priority for corrective action or preventive measure.

Design FMEA and Process FMEA

The life cycle of any product can usually be separated into five main phases: (1) concept/planning; (2) design/development; (3) production/manufacturing; (4) repair; (5) disposal. However, FMEA technique is generally carried out in product design or manufacturing process. According to different phases and different objectives, focusing on the design or the process, FMEA can be divided into two types: the design FMEA and the process FMEA. Some descriptions of this two FMEA types are described as follows:

1. Design FMEA (DFMEA) is used in the product design stage by identifying known or potential failure modes, and then ranking the failure modes according to the respective effects on the product. The common

effects on product include hazards, product malfunctions, or a shortened product life. Through the rankings based on the effects of the failure modes, design FMEA team could establish the priorities for corrective actions, and modify the design of product in advance. Therefore, design FMEA could be a useful technique to reduce the cost of manufacturing process prior to the operation process, and shorten the time to verify or test the design of the product.

2. Process FMEA (PFMEA) is utilized to identify the potential process failure modes in the manufacturing process, and then rank the failure modes based on the respective effects on the final product or customers. The failure modes in process may affect the final product and the efficiency or the safety of process. Similar to design FMEA, implementing process FMEA could establish the priorities for preventive measures, and then reduce the chance of the potential process failures occurring or the likelihood of not detecting the failures.

The Terminology of FMEA

FMEA is an important risk assessment tool to evaluate the criticality of the potential failure when a failure happens. In order to measure the risk of a failure, FMEA technique quantifies the risk of a failure mode by calculating its risk priority number (RPN). Terminology about FMEA is given below:

Potential failure mode: The manner by which a failure is observed. Generally describes the way the failure occurs and its impact on equipment operation. Failure modes are sometimes described as categories of failure. A potential failure mode describes the way in which a product or process could fail to perform its required function as described by the needs, wants, and expectations of the internal and external customers/users. It is important to consider and list each potential failure mode occurring under particular operating conditions and under certain usage conditions [Pillay, 2003].

- **Failure cause:**The physical or chemical processes, design defects, part misapplication, quality defects,part misapplication, or other processes whichare the basic reason for failure or which initial ate the physical process by which deterioration proceeds to failure[Pillay, 2003].
- **Effects of failure:** The consequence(s) a failure mode has on theoperation, function, or status of an item. Failure effects are classified as local effect, nexthigher level, and end effect. [Besterfield, 2003].
- **Severity (S):** Severity is the seriousness of the effect of potential failure mode to the next component, subsystem, system, or customer if it occurs. According to the degree of the seriousness, severity should be rated on a 1-to-10 scale. This scale is estimated based on the knowledge and expertise of the FMEA team [McDertmott*et al.*, 1996].
- **Occurrence (O):**Occurrence is the chance that one of the specific failures will occur.Sometimes, it could also be described as a probability or a frequency. The same as severity criteria, the likelihood of occurrence is based on a 1-to-10 scale, with 1 being the least chance of occurrence and 10 being the highest chance of occurrence. [McDertmott*et al.*, 1996].
- **Detection (D):** Detection is a relative measure of the assessment of the ability of the current design control to detect either a potential failure mode or the effect of a failure. If there are no current controls, the likelihood of detection will be low, and the itemwould receive a high rating, such as 9 or 10. [McDertmott*et al.*, 1996].
- **Risk priority number (RPN):** The risk priority number (RPN) is the product of the severity (S), occurrence (O), and detection (D) ratings. For example, consider a failure mode having value of 2, 3, and 2 for its (S), (O), and (D) ratings; it will have a total RPN of 12 (RPN= $2\times3\times2$ =12). This product may be viewed as a relative measure of the product or process risk. Values of the RPN can range from 1 to 1000, with 1 being the smallest risk. This value is then used to rank the order of concerns in the product design or produce process. For a relative high RPN,corrective action must be taken to reduce the RPN [McDertmott*et al.*, 1996].
- **FMEA team**: FMEA is carried out by a cross-functional team including experts andengineers involved in design, manufacturing, assembly, quality, service, and customer domains. All of the members in the FMEA team have rich knowledge and experience in the product design or manufacturing process domains, and they

can begin thinking about potential failure modes which could affect themanufacturing process or the product quality.

Organization of Thesis:

This thesis is divided into six chapter including introduction and conclusion. The chapter 1 gives the introduction to Failure mode effect analysis technique. Chapter 2 gives the review of literature of the work being done in the area of Failure mode effect analysis, and address to various problems faced in FMEA. Chapter 3 addresses the methodology proposed in the current thesis to overcome the problems of conventional FMEA. A Fuzzy methodology is introduced in this chapter along with an introduction to adaptive neuro fuzzy inference system. Chapter 4 includes the case study being done in one of Forging Industry in Punjab, it includes the data for various modes of failures, their effects and their potential causes. Implementation of hybrid neuro and fuzzy methodology on the data collected. Chapter 5 includes the results produced after implementation of proposed methodology, comparison between conventional methodology and proposed methodology and discussion about the various surface views generated. Chapter 6 includes the conclusion part of the present work done, limitation of present work and further future scope.

PROBLEM IDENTIFICATION

It was observed from literature that the most commonly used technique, to evaluate the significance of the failure modes and categorize these in several groups of risk, is based on using failure mode effect and analysis (FMEA). This methodology has been proposed in different possible variants, in terms of relevant criteria considered and/or risk priority number formulation. Using this approach, the selection of a maintenance policy is performed through the analysis of obtained risk priority numbers (RPNs). The main objective of FMEA is to discover and prioritize the potential failure modes by computing respective RPN. Even today RPN evaluation with FMEA is probably the most popular reliability and failure analysis technique for products and processes. One of the major reasons for this success is due to its visibility and easiness (Sharma et al., 2007). Different sets of the three factors can produce exactly the same value of RPN, but the hidden implication may be totally different

- The method of multiplication adopted for calculating the risk priority number is questionable.
- Also even for the most expert production staff, it is very difficult to give a direct and exact evaluation of the three intangible quantities.
- With a wider acceptance of ISO 14001 for environmental, it is very necessary to consider environmental condition in workplace.For the industries like forging and casting, the working conditions are not very favourable. Due high temperature in the shop failure can be increase and it decreases the efficiency of worker. So it is very necessary to add Environment factor with other three variables which is missing in traditional FMEA analysis.

The fuzzy set theory provides a framework to handle uncertainty due to imprecision associated with the complexity of the systems as well as vagueness of human judgment

RESEARCH TOOLS AND TECHNIQUES

During the assessment process of failure mode and effect analysis (FMEA) in forging industry there were several steps which taken into consideration. In order to identify where and how component might fail and to assess the relative impact of different failures, FMEA need to review the following:

- Failure modes (What could go wrong?)
- Failure causes (Why would the failure happen?)
- Failure effects (What would be the consequences of each failure?)

The Procedure and Form of FMEA

Failure mode and effect analysis (FMEA) is a systematic and analytic technique that is used to identify known or potential failures of a product or process. By recognizing and evaluating the failures of a product or process and their effects, FMEA team could take corrective action as soon as possible to eliminate or reduce the chance of the potential failures occurring. Therefore, FMEA plays an importance role in preventing failures occurring, enhancing reliability and safety of products, and increasing customer satisfaction.

level. Therefore, a complete analysis must span all the levels from components to the entire system.This thesis will pay attention to the process FMEA (PFMEA) of forging industry. Although the purposes for carrying out an FMEA may be different, including PFMEA or DFMEA, the steps and principles of FMEA are the same. The detailed procedure and FMEA form will be shown in following.

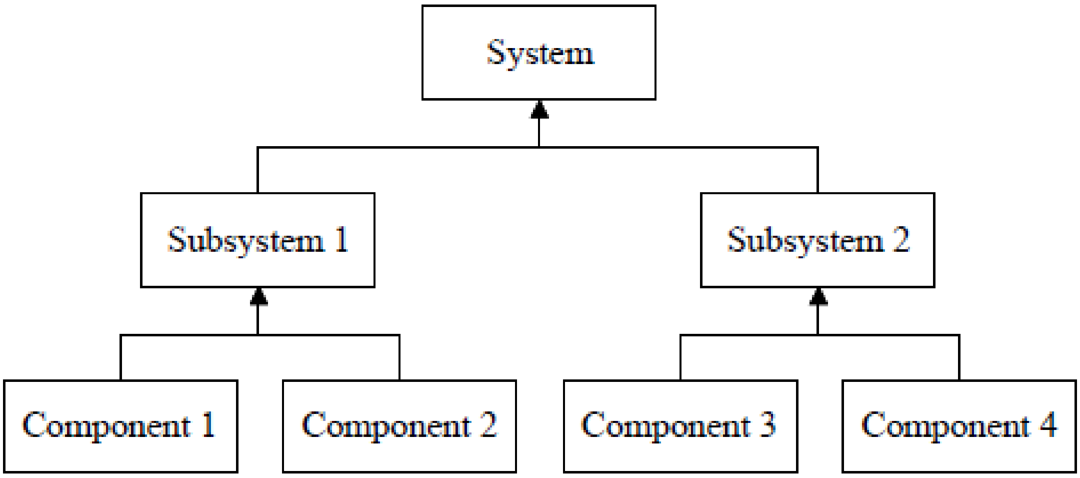

Fig. 3.1 The hierarchical structure of a system

Conclusion:

In the present work a hybrid neuro fuzzy methodology is used to develop a failure priority ranking model which uses different input linguistic variables and if then rule base is generated using adaptive neuro fuzzy inference system. The model generates fuzzy risk priority number on decision makers. Neural networks is incorporated for training, checking and testing the model from given set of data which is not in traditional FMEA which simply calculates risk priority number. A practical case forging industry is taken in the study and application of model is shown in the chapter which helps the decision maker to select an appropriate maintenance before failure occurs.

Limitations of Present Work

Apart from several benefits, the current research has some limitations as well. The limitations may be carried by researchers to carry put further work in this field. This model is only applicable for industries. The methodology followed in the thesis uses Gaussian membership function, as the membership function is automatically generated based upon the training given to the model , where as other membership functions such triangular, trapezoidal can be chosen to improve the accuracy of model.

Future Scope

There is always a scope of further improvement. In the present case of developing, the model can be further improved by incorporating other than Gaussian membership functions, such as triangular, trapezoidal membership functions which may generate more accurate model and vagueness associated with the input variables can be tackled in a better manner. Further, more number of input variables may be taken to generate the model, which gives more accurate results.

Implementation and evaluation of this model can be one of the future fields, to which work can be done to improve the functionality. After evaluation rules can be modified accordingly to make system more accurate and reliable.

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