SOFTWARE TOOL FOR AUTOMATED FAILURE MODES AND EFFECTS ANALYSIS (FMEA) OF HYDRAULIC SYSTEMS

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ABSTRACT

Offshore, marine, aircraft and other complex engineering systems operate in harsh environmental and operational conditions and must meet stringent requirements of reliability, safety and maintainability. To reduce the high cost of development of new systems in these fields improved design management techniques and a vast array of computer aided techniques are applied during design and testing stages. Failure Modes and Effects Analysis (FMEA) is generally used in the above industries to reduce design risks. At present FMEA cannot be carried out automatically. Although various FMEA software tools exist, they basically provide data management for a manual analysis. It is generally recognised that failure analyses are usually carried out after the system has been designed, and often after it has been manufactured. If any fundamental design flaws or safety risks in the system are identified at this stage then modifications to the hardware are often costly. The software tool for automated FMEA is based on qualitative modelling of generalised information flow (energy, information or mass) in a system, recognising that the primary functions of mechanical, electrical, thermal and/or hydraulic systems (or their combination) as well as modern neuromechanic systems (also called mechatronic systems in the mechanical domain) are the generation, transmission and conversion of energy. The paper explains some underlying principles of software operation and provides a description of the software.

KEYWORDS

Hydraulic, Failure analysis, FMEA, Sensor, Bond graph

INTRODUCTION

Offshore, marine, aircraft and other complex engineering systems operate in harsh environmental and operational conditions and must meet stringent requirements of reliability, safety and maintainability. Failure Modes and Effects Analysis is generally used in the above industries to reduce design risks. It is generally recognised that failure analyses are usually carried after the system has been designed, and often after it has been manufactured. If failure analysis subsequently reveals any problems, modifications to the hardware are often costly when carried out so late in the design process. The software tool for automated FMEA presented in this paper is based on qualitative modelling of generalised information flow (energy, information or...
Figure 1 Maintenance Aware Design concept
leakage at a pump location will result in a change in the energy level at this location, Figure 2. Introduction of a disturbance at a particular location in the system causes changes in state variables of the system which are propagated through the system both in forward and backward directions from the location of the fault, Figure 3. Thus the disturbance causes changes in the energy levels at different parts of the system and thus changes in the value of power variables at these locations. It is then possible to develop a table which relates changes in power variables to specific disturbances, [2, 3].

The analysis process is performed on a modified bond graph model (for structural faults) using qualitative dynamic analysis and on a higher level models using an algorithmic procedure. The analysis is completely domain independent as it is purely based upon propagation of energy.

If the system has a hierarchical structure, then the disturbances (failure mode) at the higher level are the results of a disturbance being introduced at lower level of the hierarchy, Figure 4. At the lowest level, disturbances are caused by structural faults i.e. faults induced by changes in the geometric and/or material properties of an element and tribological pairs or changes in temperature. Before failure analysis is performed, the function of the system should be established. This will yield information about the behavioural and structural properties of the design under consideration.

Software
The software which has been written in JAVA, allowing it to be run under most operating systems, is currently under tests. Various components of the software are shown in Figure 5. The software is designed to facilitate stepwise or automatic determination of failure modes and effects. The process of FMEA is carried out in a number of steps.

In the Modelling step the model is built using provided models of components, Figures 6 and 7. After the model is constructed the FMEA model is translated into bond graph model and the integrity of the model is automatically checked. At the same time controllability of the system can be assessed using method described in [4], Figure 8.

In the Analysis step the top event (a component whose operation is under consideration) is nominated and faults are propagated through the system. The next step is generation of FMECA reports (in XML and HTML format) which are produced using default criticality assessment. The criticality maybe subsequently
re-evaluated by accessing criticality tool, [5]. This tool allows either fuzzy (linguistic) or crisp (numeric) assessment of criticality, Figure 9.

After propagation is completed sensor selection procedure takes place. In the first step minimum number of sensors using complementary algorithm, [6], and their location is evaluated for each level, and a choice of sensor locations is presented, Figure 10. If designer is not happy with the sensor at a particular location he may investigate sensors on a lower level which will provide indirect indication of faults on the higher level. When the selection of the sensor is completed the observability of the system using selected sensors is checked by analysis of the bond graph model of the system. Lower level (component level) faults are modelled directly using the bond graph approach, the pre-defined faults are then associated with faults in the component. These faults are determined by propagation in the bond graph model of component. The results of this analysis is passed to procedure which generates FMECA reports. Again criticality of component faults can be assessed either using fuzzy or crisp evaluation.

Faults which cannot be evaluated using energy disturbance method are represented as paired concepts (e.g. contamination - wear, vibration - noise) and evaluated using Fuzzy Cognitive Maps, Figure 11, using approach outlined in [7]. This technique when completed will be integrated with functional analysis of the system.

CONCLUSIONS

This paper describes engineering principles and the implementation of an automated Failure Mode and Effects Analysis. The method is based on a qualitative analysis of power flow in the system in response to disturbances and the separation of the functional and structural
Figure 8 Java Bond - bond graph automatically translated from FMEA model (insert shows results of simulation)

Figure 9 Fuzzy RPN - fuzzy logic based evaluation of criticality (insert shows panel for entering severity, criticality and occurrence of faults)

Figure 10 Fuzzy Minimise - selection of minimum number of sensors
modes of failures. By separating the system functional behaviour from the behaviour of its components, it is possible to develop a suite of failure models of standard components which are re-usable. Further work will be directed towards developing techniques for handling feedback systems, multiple faults and redundancies in a system.

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REFERENCES