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Research Article

THE DIAGNOSTICS HEALTH MANAGEMENT APPLICATIONS OF A FUEL SYSTEM FILTER, FOR COMPLEX SYSTEM DISTRIBUTED INSTRUMENTATION

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ABSTRACT

Filter is one of the most essential components of any vehicle fuel system. The filtration of debris and or contaminations such as: dirt from fuel, rust particle form tank, moisture etc. is effectively carried out by the filter to enable vehicle healthy in good condition. Filter clogging is hazardous to vehicle life hence it leads to failure mode which causes reduction in system performance and efficiency. The test bed module is used to achieve the filter clogging scenarios in the laboratory with respect to fuel system test rig and filter clogging diagnostics. The diagnostics applications are focused on how to determine the health status of component or subsystem and determine the faults severity that is capable of reducing the fuel system efficiency or total breakdown. The clogged filter fault scenarios will be emulated on the test rig using the direct proportional valve (DPV). The percentage opening of the DPV is carried out on the diagnostics test rig to determine the filter healthy and faulty condition. The NI cDAQ 9172 which have the capability to acquire data from the hardware component (DPV) is configured to control the subsystem. The data obtained from the DPV, during the test period is represented on the graph to represent the filter healthy and faulty condition. The healthy condition is determine by the percentage opening of the (DPV) from 100%, 80%, 60%, 40%, and 20%, while the clogged filter faulty condition scenarios is actualised by injecting fault in to the (DPV), and then gradually open from 100%, 80%, 60%, 40%, and 20%. This paper presents a data collection method for clogged filter in the laboratory on the fuel system test rig. The system response for healthy and faulty condition test results was plotted and used to determine the filter faults severity. The data driven method is used in this paper work.

INTRODUCTION

The fault phenomenon within a system is described as an external or internal factor that is capable of causing the system performance threshold to deviate from it pre-defined point, [1]. However, component failure poses an increasing concern in the maintenance of electronic, mechanical, and hydraulic equipment, [2]. The test bed fuel system comprises of mechanical, electrical, computer, and control engineering in one. The system is developed to detect, isolate and analysed the component or subsystem fault, using a graphical manner to presents information that is readable on the graphical user interface (GUI). The diagnostic application is simply the process of identifying or detecting fault in a component or a system using automated or manual concept.

The integrated vehicle health maintenance (IVHM) is aimed at making a decision that can enhance maintenance strategy through research based on real time diagnostics. This comprehensive technology that is the IVHM, allows multiple disciplines to be integrated into the framework that enables the use of diagnosis application in engineering, science and management. The diagnostics application in the recent year has aided component or subsystem maintenance.

The diagnostics approach is one of the ways to create health awareness control for the system used in engineering and science application. This approach enhances safety and reliable mode of operation in a technological system such as: aircraft, land-craft, sea-craft, and also in process industries, for example, refinery, petrochemical, and recycling plants. The diagnostic application need to be considered for safety of human life and environmental protection. The integrated vehicle health management (IVHM) system is aimed at ensuring system safety while meeting the objective of the system which is to be considered solely on fault diagnosis. The clogged filter fault scenarios will be emulated on the test rig

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using the direct proportional valve (DPV). The percentage opening of the DPV is carried out on the diagnostics test rig to determine the filter healthy and faulty condition.

The other aspect of this paper is sections as follows: section II deals with laboratory test bed, while section III discussed the diagnostics applications, then section IV is results simulation and discussion. Finally, section V concludes the paper.

Fig 1 The laboratory test rig

The Laboratory Test Bed

The laboratory test bed set up, as shown in figure 1, of this paper work, represents a UAV fuel system that can be used in other related application such as aircraft, land vehicle, and watercraft. The test-bed has similar components such as power supply, tank, pump, pipes, shut-off valve, motor, power inverter, and direct proportional valves which are used for the simulation. A test-bed is known as the point or environment where transparent and a replicable test is being conducted scientifically using simulation and computational tools. The laboratory test bed is defined as an experimental research platform for testing of the component faults detection, and isolation using diagnostic applications. The laboratory test bed allowed user to safely control the unmanned aerial vehicle (UAV) effectively, [3]. However, [4] assert, The laboratory test bed is used as a platform to investigate the component fault such as clogged filter, faulty gear pump, stuck valve, leaking pipe, and clogged nozzle.

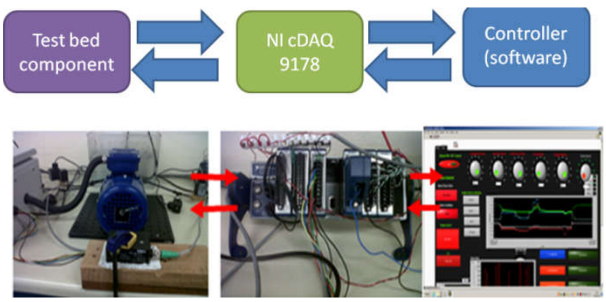

Fig 2 Test-bed hardware and software data acquisition via NI DAQ module

The hardware part of figure 2 above consist of the physical component of the test bed as mention above, where the compact DAQ modules are the point in which all component are connected as to acquire data from the respective component. Also, the PC system (software) is the environment where the Lab VIEW code is developed to simulate and read the hardware component information via the GUI. The Filter is a device used for liquids filtration which in the process results to clogging known as filter clogging. This clogging is one of the faults in which this test-bed has been developed to analyse and simulates. This paper work presents the DPV as a replica of the filter and used it for the filter clogging test, as developed in the laboratory.

System failure in some cases occurs as a result of degradation during the process of operation, which is the more reason why it is necessary to obtain the degradation data of a component or subsystem and then provide information about the reliability and the remaining useful life (RUL). However, degradation can be obvious, which can be observed physically from a point of crack until grow to failure, while in some case, cannot be observed but by taking measurement of the component performance and ascertain it degradation process, though degradation varies from component to component [4]. Filters are designed to separate particle and water from fuel. However, filter clogging caused by contamination is hazardous to engine that uses fuel system. Research shows that filter clogging phenomenon occurs as a result of contamination which produces particle in fuel solvent [5]. The effect of the accumulation of particle in diesel filter was investigated and found that it reduces the filter storage capacity by several tonnes, and also affect the economy of fuel and reduces the filter lifespan [6].

The Diagnostics Application

The diagnostics application is used to determine component or subsystem parameter and identify the point of failure due to trees or degradation. This application has contributed much in terms of fault detection, isolation and a reduction in vehicle maintenance, however, the diagnostics application have been integrated into the adaptive diagnostics and prognostics test bed (ADAPT) system, for efficient diagnostics and prognostics synthesis [7].

The data driven method is used in this paper to effectively understand the behaviour of the system and provide perfect decision-making information on how to diagnose fault and keep the system in good working condition. This method is based on the assumption that the system data remain unchanged until fault occurs in the system. However, failure in complex system such as; information technology and communication, aerospace, data serves, electrical power grids, and healthcare system have motivate researchers to prioritise effort in integrated vehicle health management (IVHM). [8] Assert, data driven method is developed for complex system diagnosis and software health.

However, this paper work have device a diagnostic mean for filter clogging by allowing a flow through the direct proportional valve and then control the valve by opening from 100% - 30% which represents fault injection, and at each point of opening, data are collected and analysis to determine the filter status. The filter degradation or clogging response is obtained on the graph. The filter status is then demonstrated by opening the valve to 20% which shows a clogged condition as the flow rate decreases and the pressure increases, also, a 50% opening of the valve shows that the filter is at a mid-life condition, which indicates that the filter is clogging gradually, while a 100% opening of the valve shows that the filter is healthy. [9] Highlight, flow rate, and pressure is an important factor that shows filter degradation, hence an increase in pressure through the direct proportional valve and a decrease in flow rate indicate a clogged filter. The clogging filter and other faults scenarios as discussed above shows that the fundamental factor that can be used to determine the component or subsystem RUL is by setting up a degradation profile to account for the clogging phenomenon, using the test-bed to emulate the faulty component occurrence through the DPV. The clogging phenomenon and faults analysis on different faulty component or subsystem have been discussed in this paper work.

RESULT ANALYSIS

The data samples obtain during the test analysis is represented on the graph below, shown as: (a) healthy condition and (b) faulty condition. The graphical representation of figure 3 below shows the component healthy condition data. While that of figure 4,5and 6 shows the faulty condition.

Healthy condition test

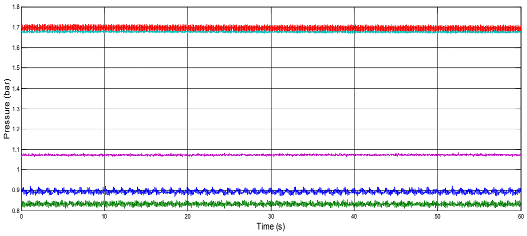

Fig 3 health condition test result

Faulty condition test

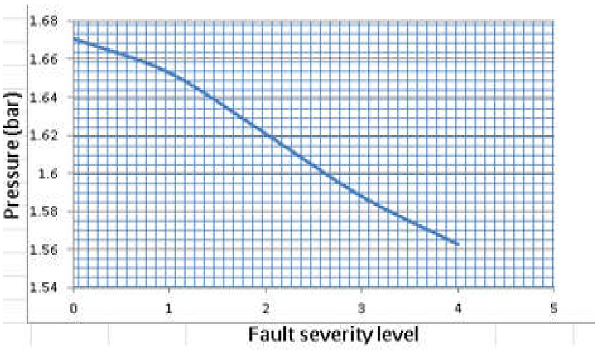

Fig 4 faulty condition test analysis

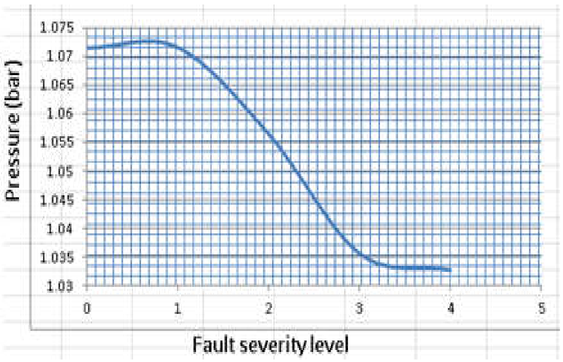

Fig 5 faulty condition test

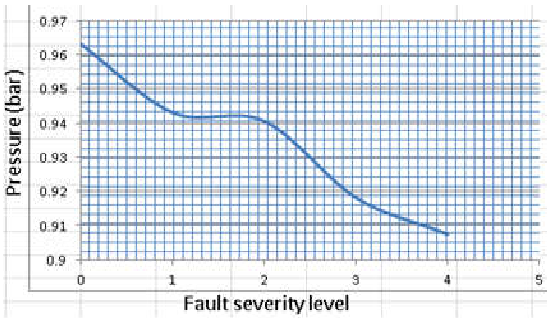

Fig 6 faulty condition test analysis

The healthy and faulty condition test was carried out by the percentage opening of the DPV and the sample obtained for each one minute test was plotted as shown in figure 3, 4, 5, and 6 above.

DISCUSSION

The discussion section of this paper work is focused on the result obtained from the simulation and analysis of the healthy and faulty condition case scenario. The healthy condition case scenario was thoroughly investigated by setting the DPV1 at 100%, DPV2 at 0%, DPV3 at 100%, DPV4 at 0%, and DPV5 at 100%. The characteristic of the graphical representation of figure 3 shows the component or subsystem healthy condition. However, a repeatability test was also carried out to verify the healthy condition phenomenon by calculating the mean.

$$\bar{x} = \sum_{i}^{N} xi / n \quad (1)$$

Where x_i is the sum of occurrence in each healthy test carried out and i ranges fromi_1, i_2,.....i_n. And n is the number of measurement in the set. While the graphical representation of figure 4, 5, and 6 shows the system faulty condition scenario.

CONCLUSION

The data obtained from the faulty component or subsystem test conducted, considering the fault severity level is used to perform the fault diagnostics analysis to determine the remaining useful life (RUL) and end of life (EOL) of the component. where at 100% and 80% opening which correspond to the fault severity level of 0 to 1, shows that the filter is healthy, but between 80% and 60% opening which correspond to the fault severity level of 1 to 2, indicate the filter mid-life, similarly between 60% and 40% opening corresponding to the fault severity level of 2 to 3 shows the filter RUL and between 40% and 30% opening corresponding to the fault severity level of 3 to 4, represents the EOL.

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