DEVELOPMENT OF A PROTOTYPE KNOWLEDGE-BASED SYSTEM FOR TROUBLESHOOTING OF AIRCRAFT ENGINE AND PARTS – A CASE STUDY OF CESSNA CARAVAN

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ABSTRACT

Malfunction and breakdown are ordinary causes of aircraft engine failure. Repair of malfunction of engine is not an easy task to perform. Generally, experts with multitude of experiences and knowledge are needed for this purpose. In the absence of these experts a knowledge-based system can be used to partly solve this problem. This paper presents the development of a prototype knowledge-based system in monitoring, diagnosis, detection and rectification of a Cessna Caravan aircraft engine to assist engineers, mechanics and technicians in their routine works. Troubleshooting of aircraft engine and parts employed knowledge-based knowledge system to act in a way similar to that of human experts in an aircraft maintenance field by using If-Then-Else rule based system. The defaults of the engine are classified into four modules namely start module, operating module, operation and performance module and lubrication problem module and more discussion is given on lubrication problem module.

Keywords: Knowledge-based system, Lubrication system troubleshooting, Aircraft maintenance, Expert system

1. INTRODUCTION

The advancement of technology in recent years has created a new medium of communication through multimedia technology. This new medium of communication is faster, easier and safer. In this connection, technologies in aircraft and aviation have also grown rapidly. Aircraft maintenance is a task generally accomplished by aircraft mechanics and their task and according to regulations need to be checked by expert engineers for approval and for any matters related to repair instructions. It is particularly true when the detailed explanation of the system function, together with the backed-up study of the actual hardware have taken place or they have undergone the training program along with years of working experience. These are time-consuming and very costly. All these issues have inspired the search for alternative approaches and techniques. It is reported by Friend (1992) that good trouble-shooting mechanics employ a mental approach, which enables them to diagnose problems, which they have either normally encountered or not.

In the past, some research efforts have been carried out in the area of troubleshooting of aircraft engines. Goker and Kuru (1990) developed a knowledge-based system related to troubleshooting of aircraft of Airbus-310. It was basically divided into four different types of knowledge viz. troubleshooting tree, part specific data, aircraft data and classification data. Each effect and recovering of an aircraft engine were studied and tested frequently (closed-loop) to ensure the reliable of the system and the effectiveness of the engine function after it was repaired. The main source of the troubleshooting tree in the knowledge base was the Troubleshooting Manual (TSM) of Airbus that comprised important questions and the answers.

Luxhoj and Williams (1996) developed an advanced decision support system for aircraft safety inspector with the objective of refining 'alert' indicators for national comparison purposes. It gave signals on potential problem areas by types of aircrafts for safety inspector's consideration. Integration was examined on two levels: i) integration of various technical components of the decision support system ii) integration of the decision support system with individual behavior, management systems, organizational structure and organizational culture across both formal and informal dimensions. They used new prediction methods, such as artificial neural network, which were proven to be useful for forecasting of removal and inspection dates for engines, assemblies and components. One of the problems occurred in developing neural network was how to determine the point of training where the neural network provided its best result. The database contained quantitative data such as age, estimated flight hours and estimated number of landings.

The work by Vingerhoeds et al (1995) was concerned with the development of artificial intelligence technology to enhance offline and online condition, monitoring and fault diagnosis and to integrate these two developments into a closed loop diagnosis tool for complex system in modern transportation, online fault

diagnosis for trains, and off-line aircraft engine condition monitoring. The operational diagnostic tasks involved alarm handling, troubleshooting for corrective actions, dispatching or traffic control. These tasks were performed on on-line basis where the crews were adhering strictly to real time requirements. Off line diagnostic tasks involved the handling of recorded data, condition monitoring, and organization of corrective and preventative maintenance. Four diagnostic tasks were identified such as off and on board troubleshooting for immediate repair actions, dispatching and detailed maintenance. The system aimed to develop software tools for which the initial domain knowledge and the knowledge gathered during operation can be used directly for multiple diagnosis tasks. Kamel (1995) discussed the design and implementation of a prototype rule base expert system for a naval aircraft flight record. This expert system includes the update operation that triggers the testing of an integrity rule, a specification of the condition to be tested and the action to be taken in the case of attempted violation.

This research, which carried out to assist new technicians, mechanics and engineers in the absence of experts by developing a knowledge-based system for troubleshooting of aircraft engine and parts is presented.

2. KNOWLEDGE-BASED SYSTEM (KBS)

A KBS or expert system is a computer system that consists of computerized knowledge of an expert in a particular subject domain in order to provide fast and easily accessible knowledge in a practical way. It is a branch of Artificial Intelligence that gathers data automatically, without the need of human expert, to solve problems that normally require human intelligence (Cartwright, 1993). In the absence of experts, KBS can be used to make decision, to solve problems or queries or in most cases, it also acts as a support system for experts in an interactive way (Sapuan, 2001). The intelligent program of a KBS consists of an inference engine and a knowledge base. Closely related with this intelligent program is a data or fact base. The inference engine manipulates the knowledge represented in the knowledge base to develop a solution to problem(s) described by the information in the data base (Gonzalez and Dankel, 1993).

3. OVERALL SYSTEM DESCRIPTION

To accomplish the system, various processes were carried out, starting from collecting the related data of the engine and parts until finally user could use the system to diagnose the failure (see Fig. 1).

3.1 Knowledge Abstraction

The Royal Malaysian Police Air Wing located at Kuala Lumpur, Malaysia is the pilot site for the system development. The development of a KBS requires many problems to be tackled. One of them is that much of the expert knowledge is heuristic in nature and very difficult to gather. All information about the maintenance and fault diagnosis processes for all aircrafts are compiled by the department maintenance personnel. The Air Wing also provides expertise and knowledge that its engineers and mechanics practiced in dealing with all the daily aviation maintenance problems.
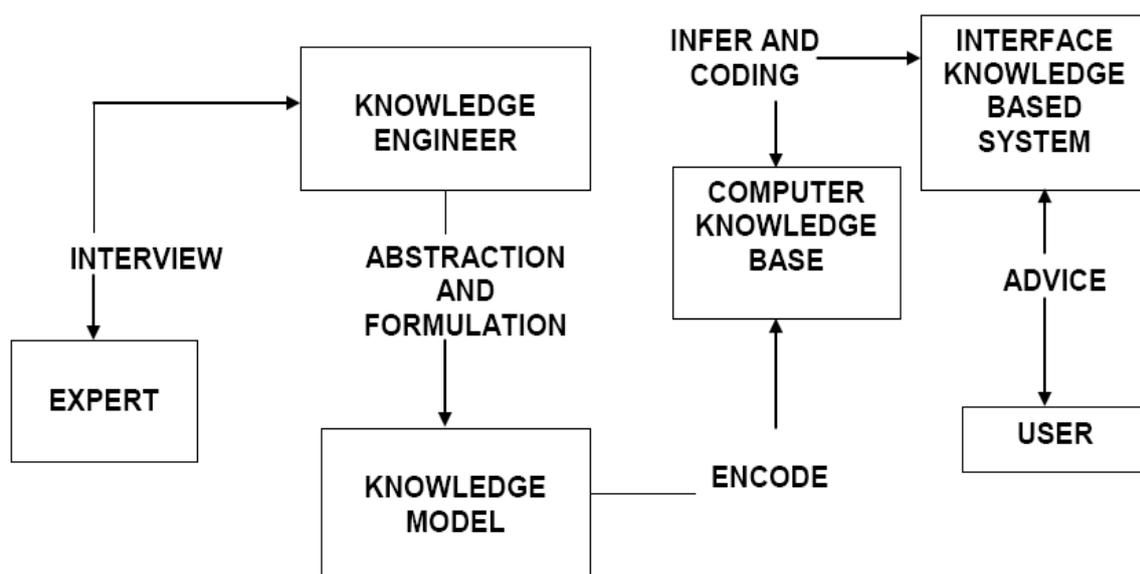

Fig. 1: System architecture

3.2 User Interface

A user interface was created using buttons, text images and bitmaps. The user interface incorporates and organizes data that have to be evaluated for further evaluation (Sapuan et al., 2002). Microsoft visual basic 6 (VB6) was used as the tool for the study. It was chosen because it was fast and easy to create application for Windows. It was provided with the Graphical User Interfaces (GUI) to make coding more easily. User interface (see Fig. 2) shows the title of the system and several buttons such as Home, About, Model, Export, Gallery and IJETTS. These buttons were shown at every screen to enable user to explore all screens. They are described in detail as follows:

   i.   Home – to shows the title of the system.
   ii.   About – to show some information about the system and contact person telephone numbers and addresses.
   iii.   Model – to provide database for the aircraft's model and part in Malaysia such as hangar, model, manufacturer, unit, application, engine and other details.
   iv.   Export – to provide the export database function where the user can export the data using the password given and then to convert to the data into Microsoft Excel.
   v.   Gallery – to show several types of Aircraft's engine and part pictures.
   vi.   IJETSS – to work the Intelligent Jet Engine Trouble-shooting System.

User interface was designed using label, text, image, bitmaps and button so that user was able to click on it to move to next screen.
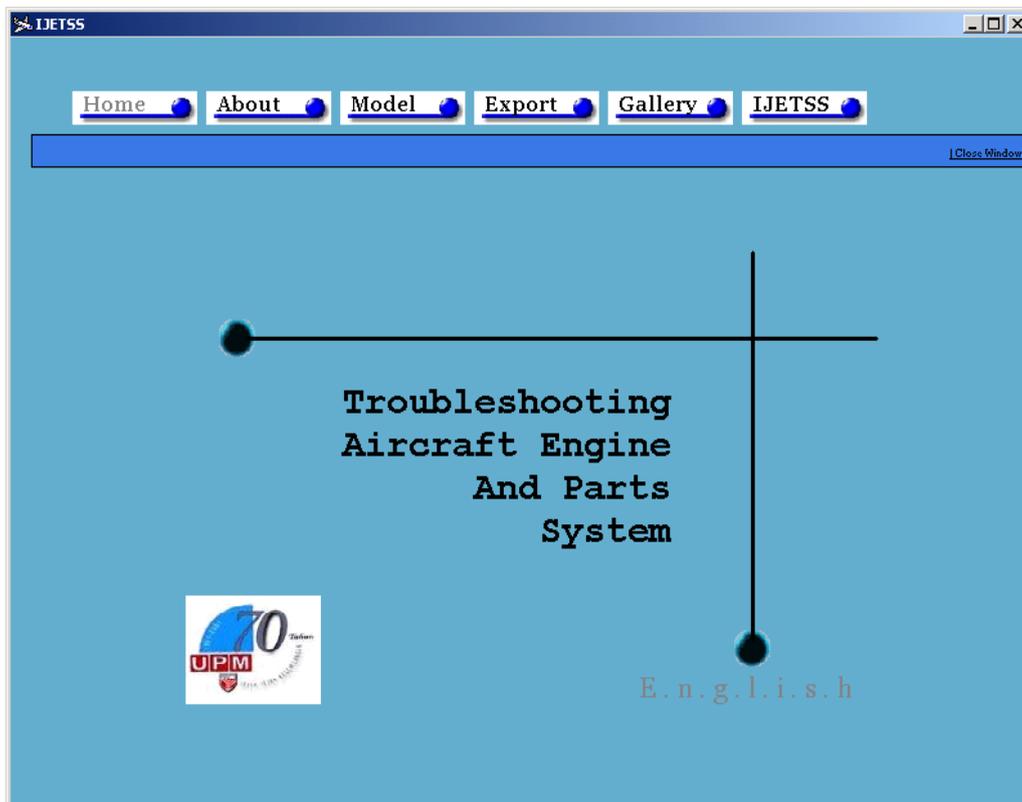

Fig. 2:User interface for the main menu

3.3 Troubleshooting of failure in aircraft engine

Information on engine and its failure were gathered by interviewing the experts on Cessna Caravan engine. Table 1 shows the specifications of aircraft model Cessna Caravan. Other sources of relevant information (Anon, 1995; CESCOM, 1995), such as the 208 Aircraft Logbook (CAP 408)(CESSNA CARAVAN, 1995), Civil Aviation authorities (CAA) and Engine Logbook CAP 391 (CAA) (Anon, 1995) are consulted as part of the development process. In addition, other related information was gathered through reading books, magazines, journal papers and also from the related web site. Then, the entire information are combined and separated according to engine common failure factor. In troubleshooting system for aircraft engine and parts, all knowledge of an expert are kept in database, it was studied and processed before the system was able to make a precise and correct decision.

Table 1: Aircraft specifications

Model	Cessna Caravan – 1 (CE-208)
Type	Fixed-Wing, Light transporter plane
Manufacturer	Cessna Aircraft Co., Canada
Serial number	20800229
Engine model	PT6A-114
Type	Free turbine
Type of combustion chamber	Annular
Working fluid	Fuel/ air mixture
Compression ratio	7.0:1
Propeller shaft	Rotation: clockwise configuration: flanged
Dry weight	158.7 kg
Oil consumption	0.091 kg/h
Length	1,575 mm
Diameter	483 mm

The KBS used the knowledge and ability of experts. Problems were not only solved by mathematically provable solutions, but also be resolved with the help of vague knowledge, rules and chains of deductions. Expert knowledge was presented in simple if-then relations. To develop the system, the study and research was executed beginning from determining the main problem and then it was divided into several sub problems commonly occurred ranging from small problem to complicated troubleshooting aircraft's engine. Four categories of faults have been studied, which are starting problem, lubrication fault analysis, operating fault analysis and operation and performance check fault analysis (see Fig. 3). Table 2 shows the example of breakdown of the fault category related to the aircraft trouble-shooting problems.
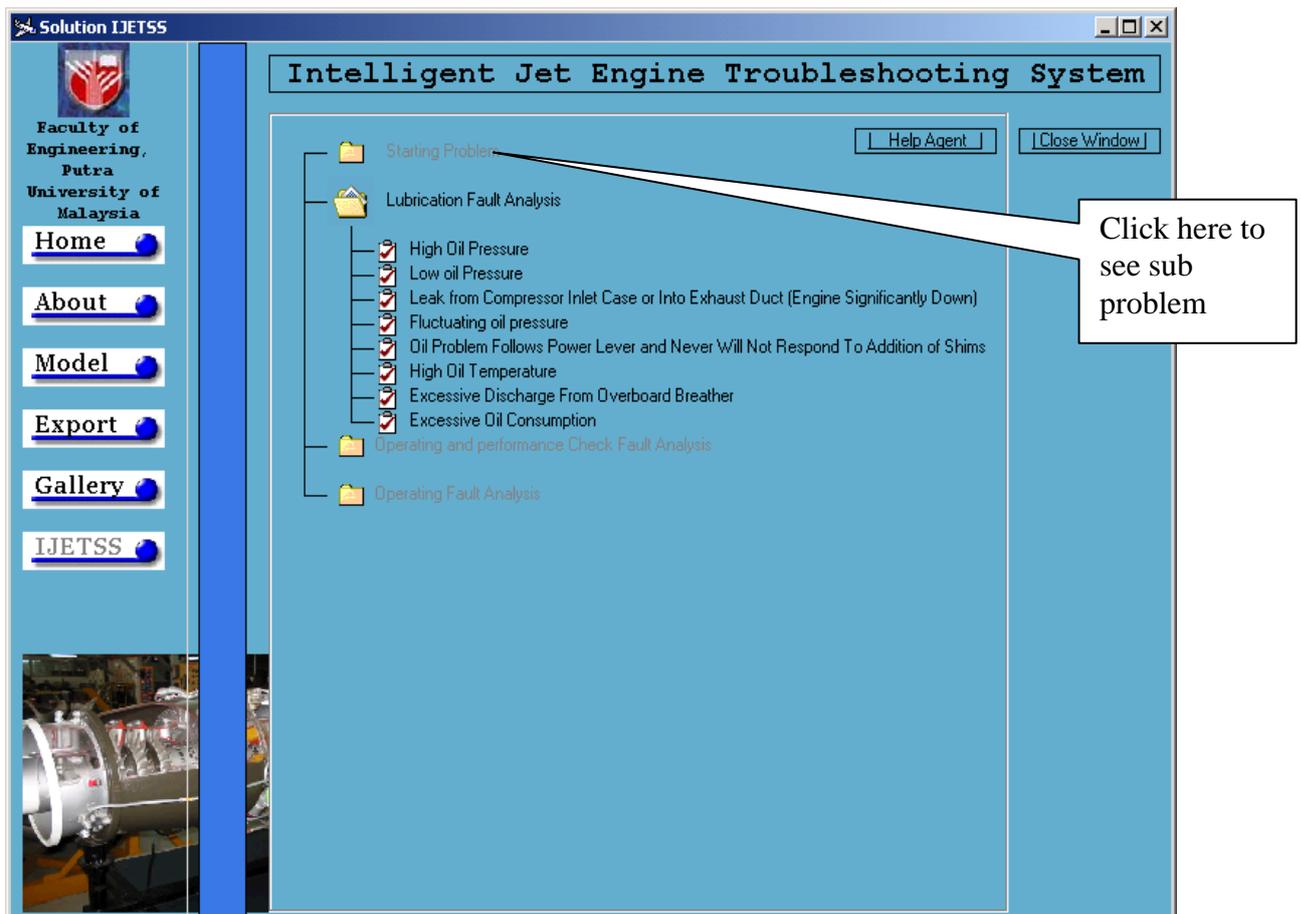

Fig. 3: User interface for troubleshooting of aircraft engine and parts – four main problems
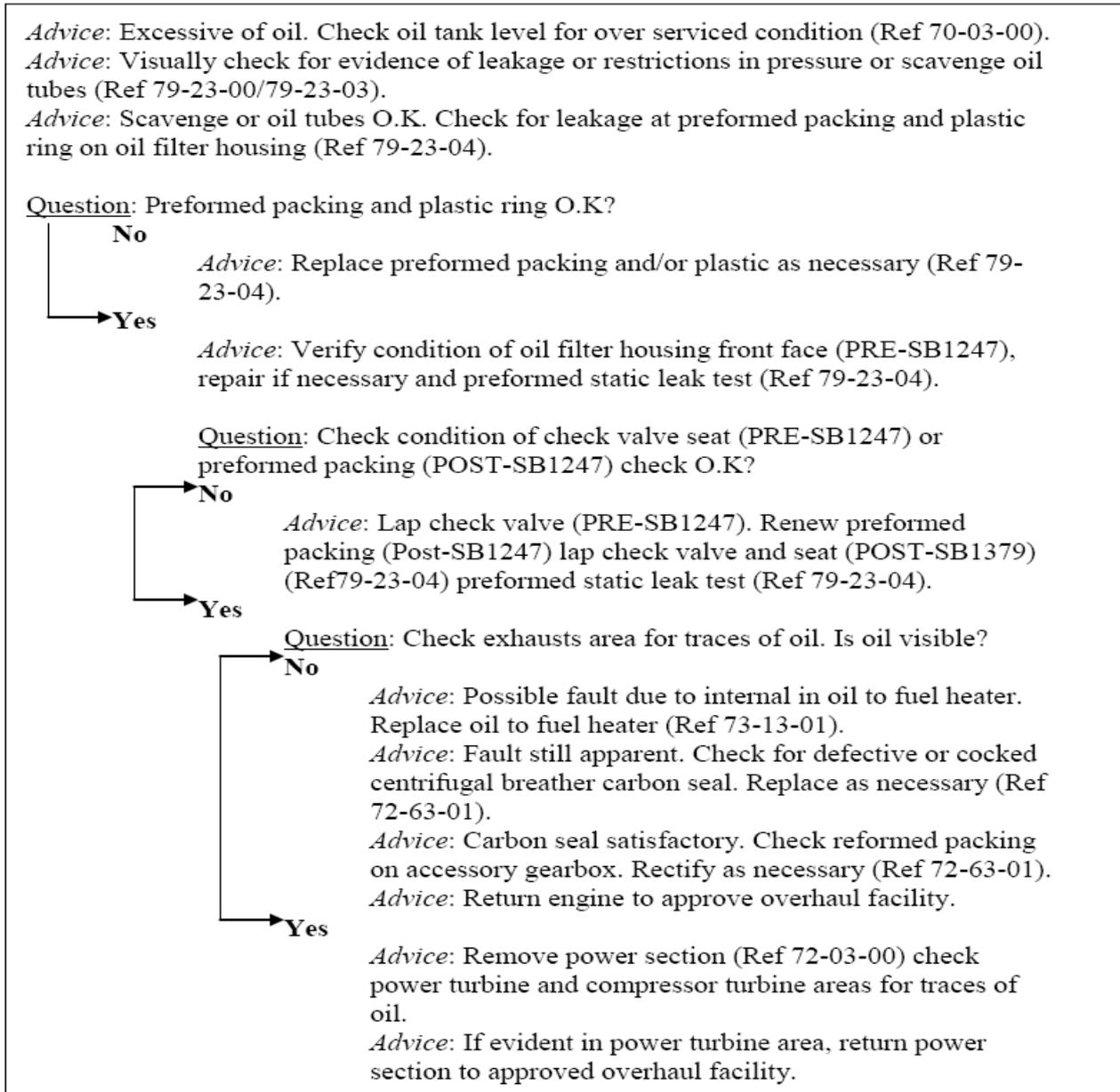
Advice: Excessive of oil. Check oil tank level for over serviced condition (Ref 70-03-00).
Advice: Visually check for evidence of leakage or restrictions in pressure or scavenge oil tubes (Ref 79-23-00/79-23-03).
Advice: Scavenge or oil tubes O.K. Check for leakage at preformed packing and plastic ring on oil filter housing (Ref 79-23-04).

Question: Preformed packing and plastic ring O.K?

   No

      Advice: Replace preformed packing and/or plastic as necessary (Ref 79-23-04).

   →**Yes**

      Advice: Verify condition of oil filter housing front face (PRE-SB1247), repair if necessary and preformed static leak test (Ref 79-23-04).

      Question: Check condition of check valve seat (PRE-SB1247) or preformed packing (POST-SB1247) check O.K?

      No

         Advice: Lap check valve (PRE-SB1247). Renew preformed packing (Post-SB1247) lap check valve and seat (POST-SB1379) (Ref79-23-04) preformed static leak test (Ref 79-23-04).

      →**Yes**

      Question: Check exhausts area for traces of oil. Is oil visible?

      No

         Advice: Possible fault due to internal in oil to fuel heater. Replace oil to fuel heater (Ref 73-13-01).
         Advice: Fault still apparent. Check for defective or cocked centrifugal breather carbon seal. Replace as necessary (Ref 72-63-01).
         Advice: Carbon seal satisfactory. Check reformed packing on accessory gearbox. Rectify as necessary (Ref 72-63-01).
         Advice: Return engine to approve overhaul facility.

      →**Yes**

         Advice: Remove power section (Ref 72-03-00) check power turbine and compressor turbine areas for traces of oil.
         Advice: If evident in power turbine area, return power section to approved overhaul facility.

Fig. 4: Example of lubrication fault analysis

Table 2: Examples of breakdown of the category problems

CATEGORY	PROBLEMS
Starting	No indication of engine RPM, delayed light-up
Operating	Hooting or humming sound, failure to decelerate
Operation and performance	High fuel flow at altitude, fuel flow fluctuation
Lubrication	High oil pressure, leaking oil in compressor inlet

Users need to click at the problem option given as appeared on the screen, when the question appeared user has to choose between "Yes" or "No" button to determine the problem until the end of question before the solution was suggested by the system. The system used forward chaining meaning it began from knowing the problem of engine and it parts, then ending with the solution. The system provides "help agent" to assist users. Fig. 4 shows how each problem was solved manually by the expert system to prove the flow

associated with lubrication fault analysis. The lubrication fault analysis applies forward chaining rule, i.e. the inference engine attempts to work from the features to the solutions. Before each question from sub problem begins, several advices were given to provide some preliminary ideas to make a few modification and adjustment at the faulty engine. In order to facilitate the development of a rule-based system, each problem is sequenced in a flow that resembles the decision tree model.

4. DATABASE AND SYSTEM CAPABILITIES

Database is a core part of the system to store important data and information. The database consists of data for aircraft type information, manufacturer's information and hangar information. These data were provided by The Royal Malaysian Police Air Wing, Kuala Lumpur, Malaysia.

The troubleshooting system for aircraft engine and parts was successfully developed in this study. The KBS system was developed only for a particular model of engine and it is not a generic troubleshooting system. Each model has its own parts and the type of treatment also differs according to the specific engine. Searching function also needs to be enhanced with a lot of information to assist user retrieve information that they desire. Fig. 5 shows the example of "Lubrication Fault Analysis" result from the system.
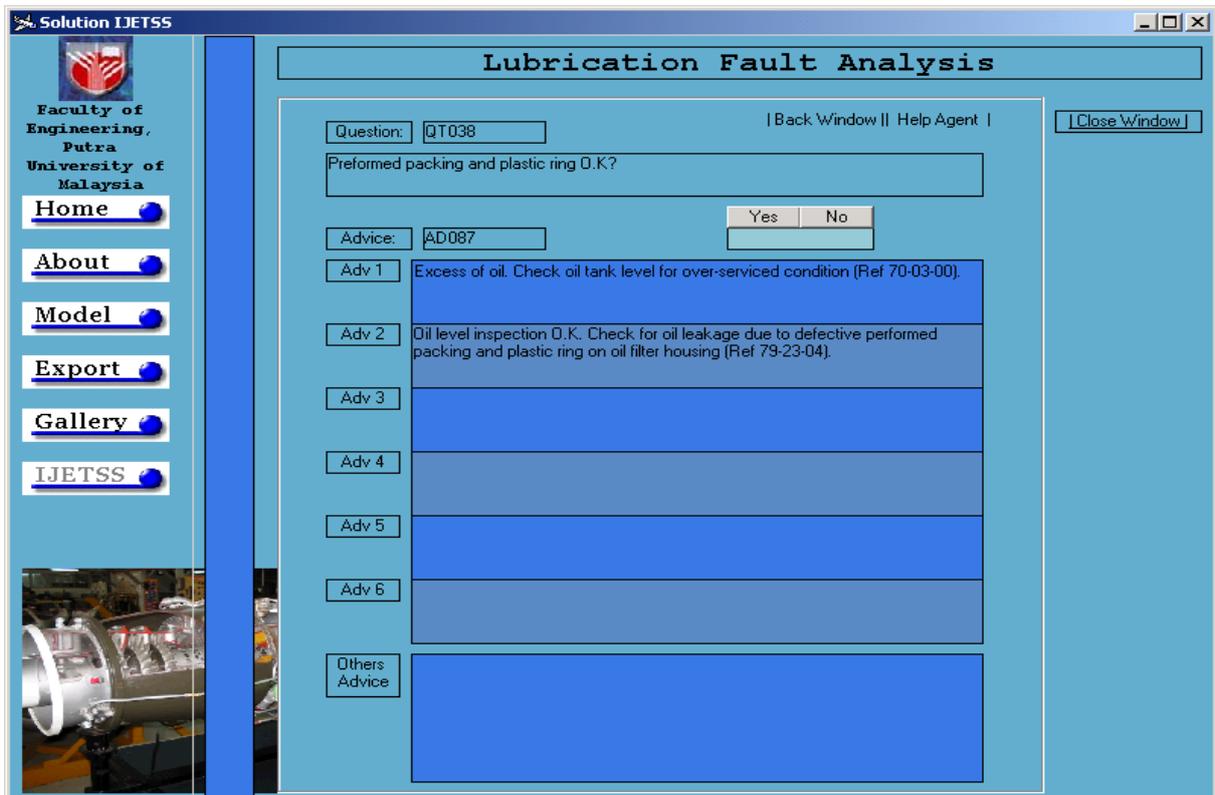

Fig. 5: Lubrication fault analysis result

The system has extra functions such as to help users to identify, recognize and familiar with other models of aircraft's engine. Therefore, the search engine's function is mainly to find name or related information from other models of aircrafts and parts by several categories, backup files or databases, print data or form, related link, and acts as an agent to assist the users and as a security system to protect the system with illegal user and modification fix data.

The online system is developed to help user-accessing information every time and everywhere. The online and offline systems contain similar reasoning and process. The advantages of online system compared to and offline system was that, online system was accessible and in the future, the security system will add for extra protection while the offline system can be used in the computers that have not been provided with the Internet service. At the end of the process, final advices and related link are given. The link provides assistance to users to gain some additional information from suggestion web site address.

5. CONCLUSIONS

A prototype KBS for aircraft maintenance and trouble-shooting of engine failures in order to minimize the involvement of experience mechanics and engineers is presented in this paper. The system consists of four modules, namely starting problem, lubrication fault analysis, operating fault analysis and operation and performance check fault analysis. It enables the user to perform strategic procedure for handling equipment

and builds up computational assistant knowledge to the airline company. The KBS works in full interactive mode and gives reference information for the user to follow the trouble-shooting procedures.

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