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DEVELOPMENT OF GUI TYPE ON-LINE CONDITION MONITORING PROGRAM FOR A TURBOPROP ENGINE USING LABVIEW®

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ABSTRACT

Recently, the health monitoring system has been developed for precaution and maintenance action against faults or performance degradations of the advanced propulsion system which may be occurred in severe environments such as high altitude, foreign object damage particles, hot and heavy rain and snowy atmospheric conditions. However to establish this health monitoring system, the on-line condition monitoring program is firstly required, and the program must monitor the engine performance trend through comparison between measuring engine performance data and base performance results calculated by base engine performance model.

This work aims to develop a GUI type on-line condition monitoring program for the PT6A-67 turboprop engine of a high altitude and long endurance operation UAV using LabVIEW. The base engine performance of the on-line condition monitoring program is simulated using component maps inversely generated from the limited performance deck data provided by engine manufacturer. The base engine performance simulation program is evaluated because analysis results by this program are well agreed with the performance deck data. The proposed on-line condition program can monitor the real engine performance as well as the trend through precise comparison between clean engine performance results calculated by the base performance simulation program and measuring engine performance signals. In the development phase of this monitoring system, a signal generation module is proposed to evaluate the proposed on-line monitoring system. For user friendly purpose, all monitoring program are coded by LabVIEW, and monitoring examples are demonstrated using the proposed GUI type on-condition monitoring program.

NOMENCLATURE

ALT	Altitude
DAQ	Data Acquisition Equipment
GPA	Gas Path Analysis
GUI	Graphical User Interface
HMS	Health Monitoring System
MDS	Main Database Serve
Rating Code	Engine Output Conditions(Flight Condition)
RC 1	Max Take-off
RC 3	Max Climb(=Max Cruise)
RC 5	80% Max Cruise
RC 6	60% Max Cruise
RC 7	30% Max Cruise

INTRODUCTION

In operation of the aircraft propulsion system, high reliability and availability and low operational cost are very important issues for both engine manufacturer and user. Therefore recently development and application of aircraft propulsion condition monitoring and diagnostics are generalized. Especially, in case of the propulsion system which is operated for long time in severe operating conditions of high altitude more than 12km and long endurance more than 24hr, the health monitoring system must be required for precaution and maintenance action against faults or performance degradation of the engine. Therefore, the model based condition monitoring systems have been developed to enhance reliability and availability of the propulsion system, recently. The model based condition monitoring method, which can monitor quantitatively the condition of major gas path components, can realize the engine health condition monitoring by analyzing changes of mass flow parameter and efficiency of each component. [1],[2]

However, because direct measurement of these component performance parameters is not available during engine operation, it can be indirectly estimated by using changes of measurable performance parameters such as temperature, pressure, rotational speed, fuel flow, etc. Therefore, the step, which can monitor the performance trend by using performance differences between the real measuring engine performance data and the base performance data calculated by the base engine performance simulation program, must be performed prior to the engine diagnostics.

In order to build the base performance model to calculate the clean engine performance, firstly this work generates inversely component maps of the PWC PT6A-67 turboprop engine using limited performance deck data provided by engine user and considering its high altitude operating behaviors, and then develops the base engine performance simulation program using the generated component maps. Using this base engine performance model, the user friendly GUI (Graphic User Interface) type on-line condition monitoring program, which can monitor the performance trend through comparison between performance analysis results using the developed base performance simulation program and real measuring performance data, is finally developed.

ON-LINE CONDITION MONITORING PROGRAM OF TURBOPROP ENGINE

The target engine for the condition monitoring is the PWC PT6A-67 turboprop engine, which will be used for a long endurance UAV in the high altitude and long endurance operation. This engine is composed of 4 stages axial and 1 stage centrifugal compressor, reverse annular vaporizing combustor, 1 stage axial compressor turbine, and 2 stages axial free power turbine with constant speed control. Moreover it has 2 stage reduction gear box, and the power is flat-rated to 1200hp.

Figure 1 shows the schematic view of PT6A-67 turboprop engine, and Table 1 illustrates design point performance data of the turboprop engine.[3]

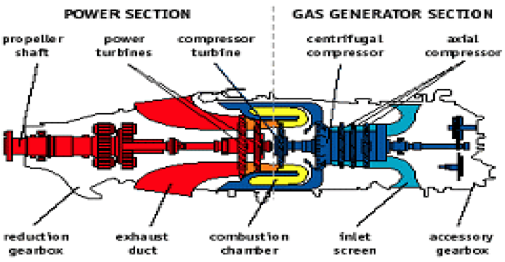


Fig. 1 Schematic view of PT6A-67 Turboprop Engine

Table 1 Design point performance of PT6A-67 turboprop

Operation Conditions	Static Standard
Gas Generation rpm	39,000
Power Turbine rpm	29,894
Propeller rpm	1,700
ITT (K)	1,113
Shaft Power (SHP)	1,726 (Flat-rated to 1200)

This work proposes a quasi-on-line condition monitoring program which can monitor the engine performance trend at almost real time in flight operation. This program is composed of three parts such as the base engine performance simulation program, the real engine performance monitoring part and the trend monitoring and display part. For user's convenience, the performance simulation program is made of GUI (Graphic User Interface) based program using a commercial program LabVIEW[4], which has various numerical analysis techniques and control functions widely used in the advanced system modeling.

BASE PERFORMANCE SIMULATION PROGRAM

The base performance simulation program of the PT6A-67 turboprop engine uses the flow shown as Fig. 2. In the program, if the generated component maps are designated, proper component characteristic values such as mass flow parameters, pressures and isentropic efficiencies are found from the component maps at given input fight operating conditions through the work and mass flow matching process. [5]

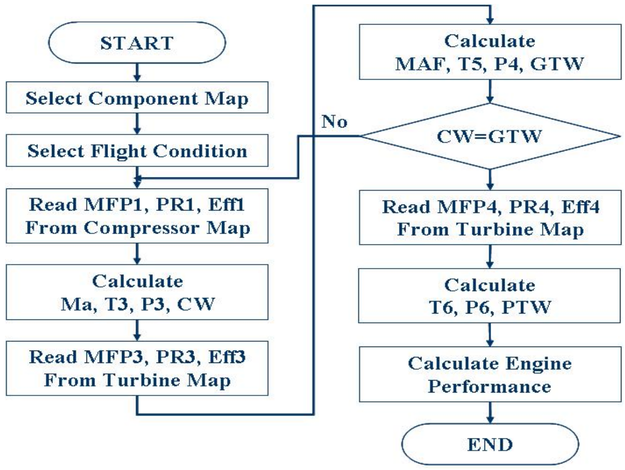


Fig. 2 Flow of base performance simulation program

Figure 3 shows the GUI-based front panel of the base performance simulation program, which can not only make input data such as operating conditions and design point performance data, but also display and save performance analysis results of major performance parameters. [6]

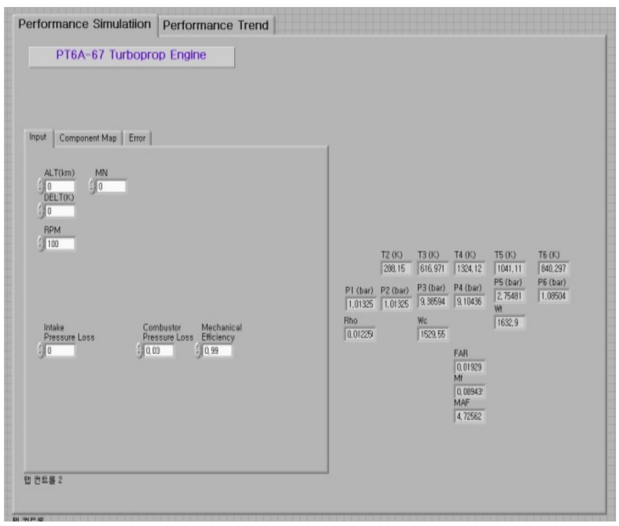


Fig. 3 GUI-based front panel of baser performance simulation program

Figure 4 shows the GUI-based subsystem blocks of the base performance simulation programming using LabVIEW, which is composed of flight and ambient condition module, intake performance module, compressor module, combustor module, compressor turbine module, power turbine module, component map search module, gas characteristic value calculation module and work matching module.

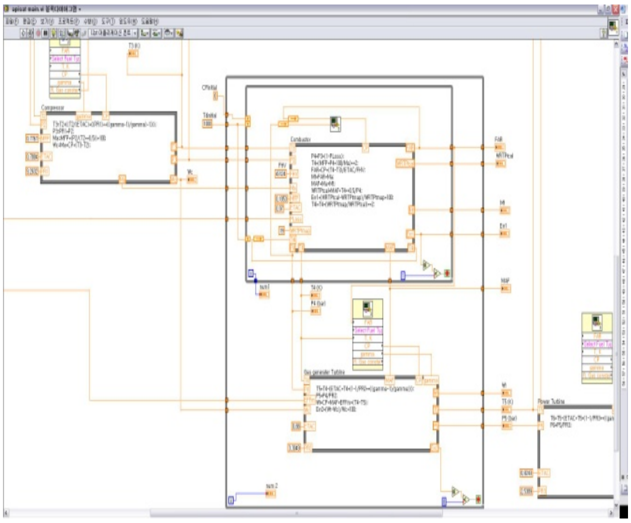


Fig. 4 GUI based block diagrams of performance simulation programming using LabVIEW

Generally, most performance simulation programs search proper component characteristic values from the component map diagrams at the mass flow mass flow matching conditions. However, this searching method takes long time to find the proper component characteristic values. Therefore, this work proposes to use the 2D look-up table shown as Fig. 5 to reduce the calculation time as well as to obtain more precise component characteristic values.

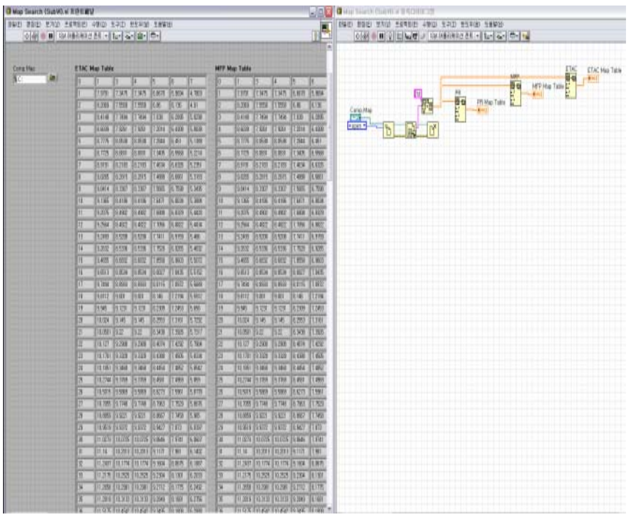


Fig. 5 2D Look-up table type component map search subsystem module

ENGINE PERFORMANCE SIGNAL GENERATION MODULE

Because the real engine performance measuring data is not available at the beginning of development of the monitoring program, the engine performance signal generation module shown as Fig. 6 is proposed to generate similar real engine performance parameter values. This engine signal generation module can generate randomly the engine performance signal within maximum 5% deviation at the same operating condition as the base engine performance simulation module

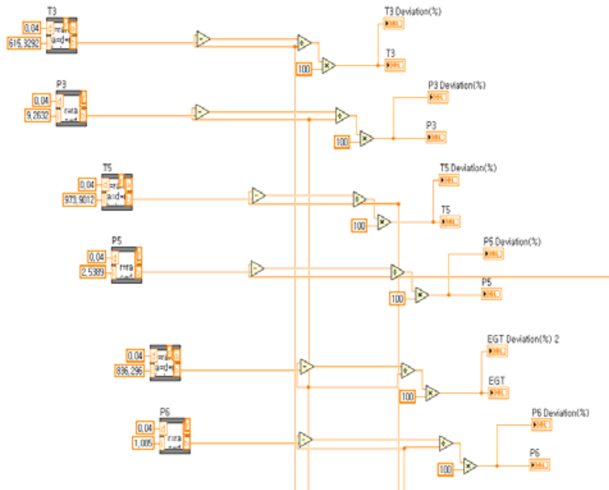
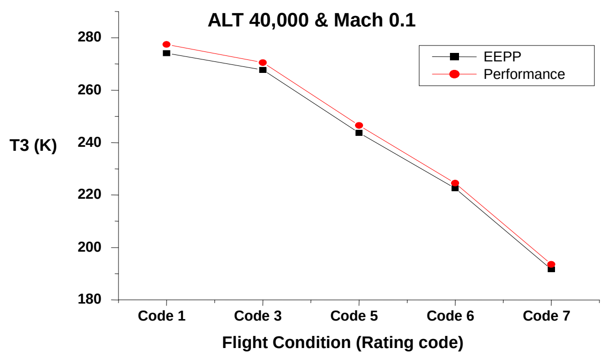


Fig. 6 Engine performance signal generation module program

VERIFICATION OF PROPOSED ON-CONDITION MONITORING SYSYTEM

The proposed on-condition monitoring program is verified by comparing with the engine performance program deck (EEPP) data provided by engine manufacturer, and demonstrated using performance engine signal generation module.

Figure 7 shows verification results of the base performance simulation program of the on-line condition monitoring program through comparing the performance results estimated by the proposed base performance program with the EEPP data. Through this comparison, it is found that performance analysis results using the proposed base engine performance simulation program are well agreed with the EEPP data within 1% error.



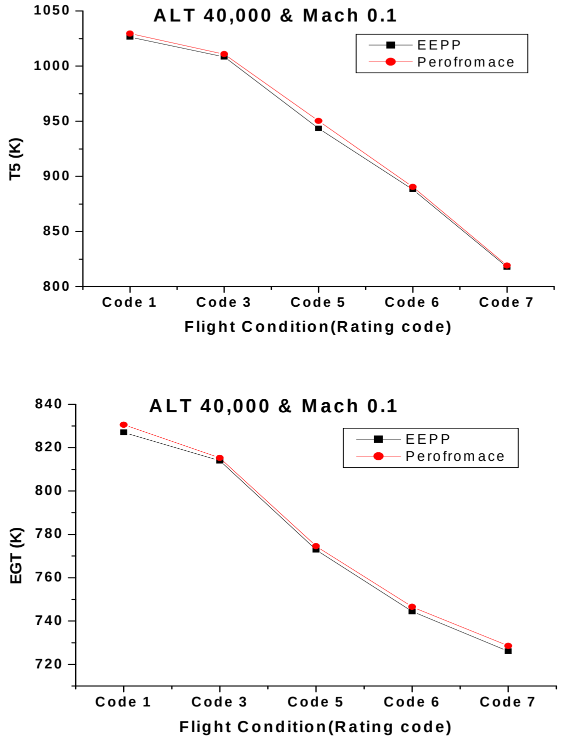


Fig. 7 Verification of base performance simulation program

In order to confirm how to monitor well the engine measuring performance data, the engine measuring signals which are virtually generated by the performance signal generator with ±4% deviations from the base performance.

Figure 8 and 9 show engine performance trend the monitoring results displayed on the front panel of the proposed on-condition performance monitoring program.

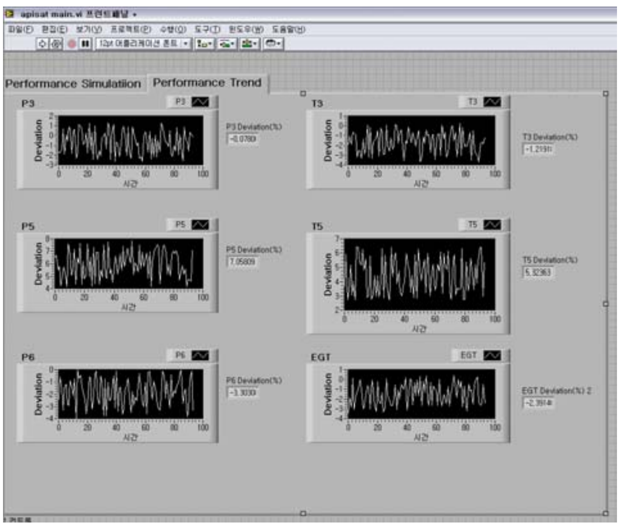


Fig. 8 Engine performance condition monitoring results displayed on front panel

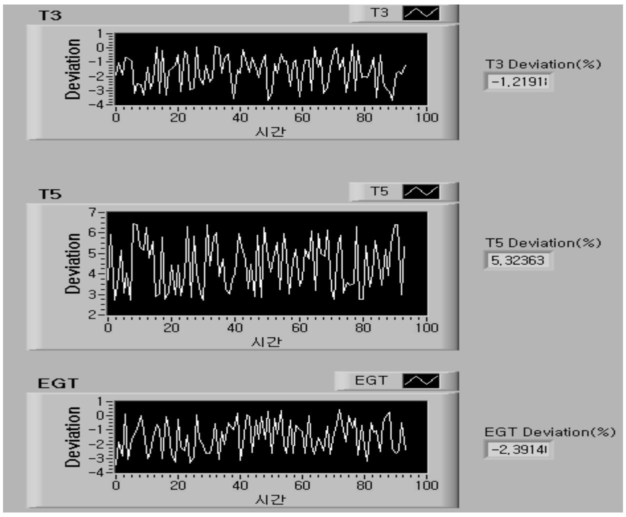


Fig. 9 Performance monitoring results within ± 4% deviation using engine performance signal generator

ON-LINE CONDITION MONITORING USING ETHERNET COMMUNICATION

Through the verification example, it is confirmed that the proposed GUI type on-line condition monitoring system using LabVIEW can monitor well the virtual engine performance signals generated by engine performance signal generator.

However, the most important issue to monitor the engine condition is how to acquire the real engine signals during long duration and high altitude flight of UAV. Therefore this work proposes the engine data acquisition system using Ethernet communication shown as Fig. 10[7].

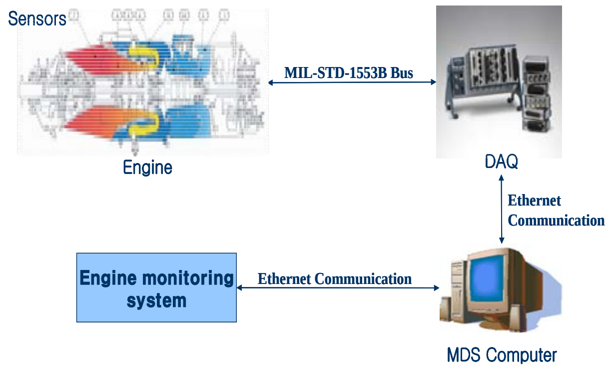
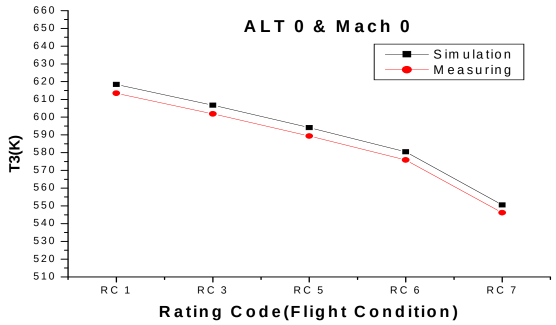


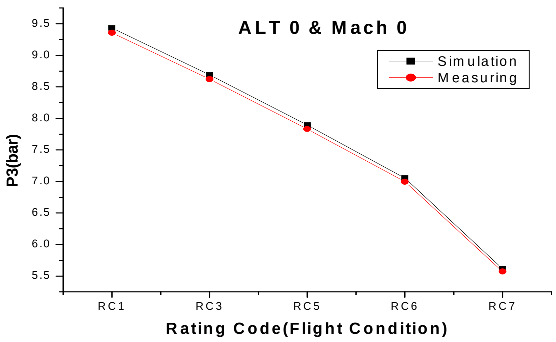
Fig. 10 Engine data acquisition system using Ethernet communication

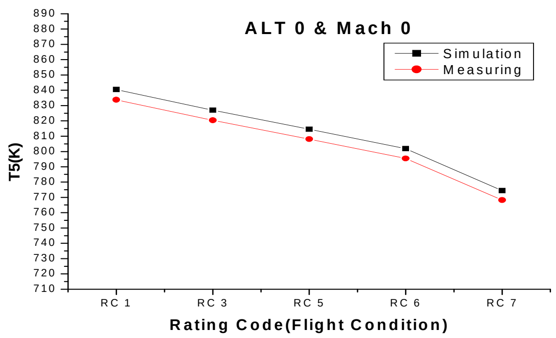
According to the proposed engine data acquisition system, engine signals obtained by sensors installed on the engine are firstly transferred to the data acquisition system (DAQ) through the 1553B Bus, and then these signals are saved at the main database server (MDS) through Ethernet communication. After bias, noise and sensor faults of the save signal data are processed at the MDS, and then the processed signal data is sent to the real engine signal generation module of the on-line condition monitoring system through Ethernet communication.

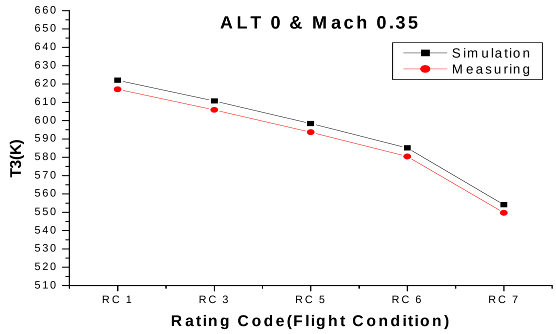
In the case of the transient flight condition, the engine signals are saved to the MDS after stabilizing to minimize the sensor error effect. Where, the data communication error process will be studied later.

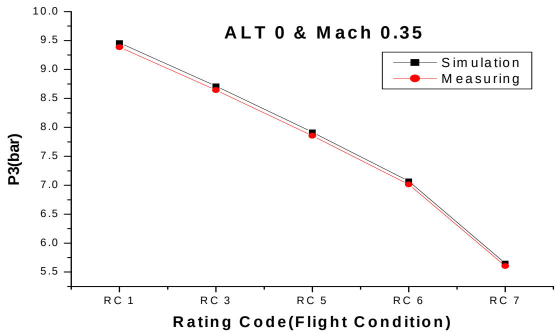
In order verify the proposed Ethernet communication data acquisition system, real engine performance monitoring data ('Measuring') acquired by the proposed data acquisition and communication system are compared with the clean engine performance data ('Simulation') estimated by the base performance program (see Fig. 11). Where the real measuring engine data are nearly clean engine performance data because they are measured at the initial engine operation. The considered operating conditions are the sea level and MN 0 and the sea level and MN 0.35. Through comparison, it is found that the maximum difference between the measuring data and the simulation clean engine data real is about 1%. Through this test example, it is confirmed that the proposed the real on-line condition monitoring system using Ethernet communication data acquisition system can be applied to the real engine condition monitoring.











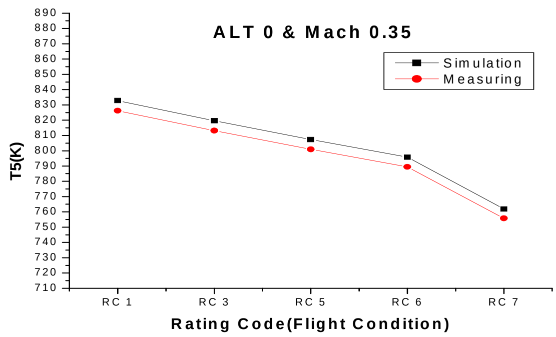


Fig. 11 Comparison of performance monitoring data ('performance') by data communication system and engine performance data ('engine data')

CONCLUSION

In this work, a GUI type on-condition engine monitoring program, which can monitor the engine performance trend through performance parameter changes between measuring performance data and base performance data calculated by the base engine performance simulation program, is developed. To provide the user friendly program, this program is coded by LabVIEW.

The proposed on-line condition engine performance program is verified by comparing with the engine performance deck data provided by engine purchaser, and demonstrated using performance engine signal generation module.

In order to apply the on-line condition monitoring system to the UAV engine during long duration and high altitude flight, the engine data acquisition system using Ethernet communication is proposed.

This program will be directly used for the real engine condition monitoring in flight operation as well as linked to the engine fault diagnostics program in development.

ACKNOWLEDGMENTS

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