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AUTOMATED JET ENGINE CONTROL AND ASSESMENT - THE SR-30 JET ENGINE

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ABSTRACT

The SR-30 is an educational model jet engine manufactured by Turbine Technologies that allows students to observe the fundamental working of turbine machinery and perform various experiments within the confines of a safe working environment. The engine comes pre-equipped with many sensor transducers allowing measurements such as pressure and temperature to be taken at various points within the engine itself. The SR-30 is setup for full manual control with switches for various stages of startup and relies on an outside source of air pressure to provide the initial rotation of the engine necessary for combustion. Although the SR-30 already includes many features, many more things can be done to improve the interface for more advanced research to be completed.

In order to achieve this, a National Instruments data acquisition system was set up to allow the machine's sensors to be observed and processed simultaneously and incorporated into a protected automatic startup sequence for the engine. Also, a throttle linkage and stepper motor were used to automate the throttle for full control by the computer and relays were put in place to allow remote operation of the switches. This fully automated system made the engine more accessible to the university as a research tool and eliminated the need for an understanding of the hardware setup for users wishing to focus on other areas of development.

System modification- Hardware Configuration: Three separate groups of modifications were made on the original engine system:

- An interface had to be provided so the manual switches could be operated via computer.
- The throttle lever and the steel cable running to the fuel valve needed to be automated.
- Finally, the data acquisition system had to be enhanced to incorporate signal detection at higher speeds. This was in preparation for the employment of the software control package.

Manual lever replacement: Originally, the fuel control valve was controlled using a cable attached to a hand-operated lever. The lever control system was replaced with a stepper motor control system. The stepper motor was attached to the fuel valve using a four bar linkage.

The fuel valve is of the needle type and is positioned on the fuel return. When the pin is rotated, a threaded pin screws down into a hole blocking the fuel return flow. Note that when the valve is closed, the throttle is in the fully opened position. This is because the valve is positioned on the fuel return line and, when closed, increases the rate at which fuel is injected into the combustion chamber. The valve is a sensitive device and should be calibrated carefully. In discussion of the throttle automation, precautions in protecting this valve will also be mentioned. The rotation of the stepper motor shaft had to be adjusted accordingly to operate the fuel valve. This is done using a four bar linkage.

The length of the crank and coupler were so chosen so that when the motors shaft completes a full revolution the rocker or the fuel valve needle only rotates between the closed and open position. Hence, the stepper motor control can not mechanically break the fuel valve by over rotating it in either direction. This effectively eliminated the need for limit switches. The motor is controlled by the Velmex Stepper Motor Controller. This in turn is slotted into the serial COM PORT of the PC and enables the PC to position the stepper motor remotely with a resolution of 400 steps per revolution. A full 180° sweep of the motors shaft results in a full sweep of the throttle therefore the throttle sweep is divided up into 200 steps.

Data acquisition system replacement: The original National Instruments' bench logger took all the readings at a rate of 60 samples per second. The new system, consisting of a National Instruments PCI 6024 E card in conjunction with a National Instruments' SCXI 1000 chassis and two National Instruments SCXI 1121 modules, is capable of reading speeds of up to 13,333 samples per second on each sensor. On the side of the engine casing is a National Instruments TBX 68 T. From the TBX 68 T is a 68 pin shielded cable plugged into a National Instruments SCB 68. In the TBX 68 T the signals are bundled into a single cable. From the SCB 68 they are again unbundled to be inserted into the modules of the SCXI 1000 chassis. The SCXI 1121 modules offer gain for the thermocouple readings and the strain gage reading for thrust. There is also a feed through module which allows for the pressure signals, RPM and fuel flow signals to be directly sent to the PCI card since these signals already have sufficient amplitudes for measurement purposes.

System modifications- Soft Computing Control: The startup logic was programmed using National Instruments' GUI programming language LabVIEW. The automated start sequence controlled the switches and the throttle of the engine to start the engine as fluently as possible. The programmed steps are summarized:

- STAGE 1: The MAIN switch is activated powering the panel electronics. The only condition that this stage requires is for the operator to have given the order to start the engine and that the EGT thermocouple is reading below 100°C (as per manufacturer's advice).
- STAGE 2: This stage proceeds three seconds after STAGE 1 successfully completes. Execution of STAGE 2 results in the IGNITION and AIR switch being turned on. This initiates the ignition spark plug and the compressed air drives the shaft to 8,000 RPM.
- STAGE 3: This stage waits for the shaft RPM reading to reach 8,000 to start the FUEL flow and ignition.
- STAGE 4: A fuzzy logic controller takes the engines RPM to the idle speed of 50,000 RPM (as per manufacturers advice).
- STAGE 6: The AIR and IGNITION switches are turned off.

Fuzzy Logic Controller: Watanabe (*reference* 2) had generated a transfer function to develop a steady state control system for the SR-30. Fuzzy logic lends itself to generating control systems for unknown models such as the start up of the SR-30. The fuzzy control system was generated by analyzing the step response of the system as shown in *figure 1*. The developed system is an ideal prequel to Watanabe's (*reference 2)* work which developed a steady state fuzzy logic control system but did not implement the controller during the startup procedure.

CONCLUSIONS

The test-bed built here was designed to allow health networks and advanced control techniques to be seamlessly integrated with the already established system in order to improve the control and maintenance of the engine. The operation of the system has been greatly simplified and is much more accessible to students. The controller also significantly reduced the peak exhaust gas temperature of the engine during startup which is healthier for the engine.

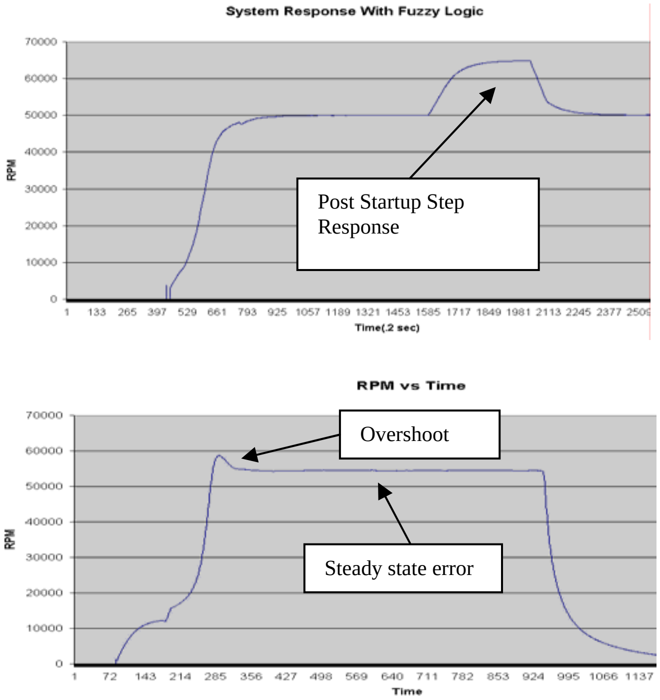

Figure 1: RPM versus time: Above- with Fuzzy controller; Below- step response without Fuzzy controller

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