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GAS TURBINE ENGINES – THROUGH IMPROVED MAINTAINABILITY TO IMPROVED OPERATIONAL READINESS IN NAVY HELICOPTERS

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Abstract

Reliability needs of the military focus primarily on operational readiness, longevity, supportability, robustness. That means product performance on demand, long useful life, repair ability and satisfactory performance over environmental extremes. Availability requirements of modern systems and equipment demand that designing for maintainability must be as important as designing for other performance characteristics.

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Customer needs are always very high. The challenge to the manufacturer or service provider is how to assess and define true customer expectations and then how to design, manufacture and sell the product to best meet those expectations. Military customer is specific. The air force is very specific but navy aviation is extremely specific. There are numerous differences between the needs of a typical customer and a navy aviation customer. Reliability needs of the military focus primarily on operational readiness, longevity, supportability, robustness. That means product performance on demand, long useful life, repair ability and satisfactory performance over environmental extremes [1]. A thorough understanding of the environment in which the product is intended to operate is the major consideration in determining the ability of a product to meet the operational reliability needs of the military. The environment is a critical factor in determining the suitability of the equipment for military use, especially in the navy aviation. Each product must provide operational capabilities which allow military forces to maintain technological and logistics superiority over a potential adversary even if it is just natural or induced environment which can be expected over the operational and maintenance portions of life cycle. Degradation or loss of these operational capabilities typically can result in immediate loss of human life and equipment (Fig. 1, 2) [2].



Fig. 1

Availability requirements of modern systems and equipment demand that designing for maintainability must be as important as designing for other performance characteristics. According to military definition, maintainability is a measure of the ability of an item to be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance or repair. You can find some other definitions connecting effectiveness and economy and efficiency.



Fig.2

There are two examples of naval helicopter engines (Fig. 3):

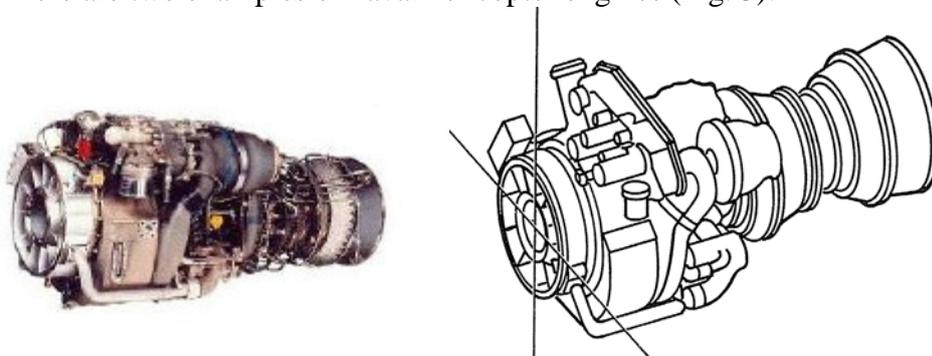


Fig. 3

The T700-GE-401 engine is a front drive, turbo shaft engine featuring a single spool gas generator section consisting of a five-stage axial, single stage centrifugal flow compressor, a

through-flow annular combustion chamber, a two-stage axial flow gas generator turbine, and a free or independent two-stage axial flow power turbine. The power turbine shaft, which has a rated speed of 20,900 rpm, is co-axial and extends to the front of the engine. The engine incorporates an integral inlet particle separator, a top-mounted accessory package, an engine-driven fuel boost pump, a self-contained lubrication system, condition monitoring, diagnostic provisions, a hydro mechanical control system, and an electrical control system or digital electronic control system (401C version) providing power turbine speed control, dual engine load sharing, temperature limiting, and redundant power turbine over speed protection. The T700-GE-401 engine also has a contingency power rating for use under one engine inoperative conditions.

Engine control system has all the components necessary for the proper and complete control of the engine. This system provides for fuel handling, fuel computation, compressor bleed and variable geometry control, PT over speed control protection, over temperature protection and torque matching. This system is self-contained and does not require external electrical power for any controlling functions. It also allows replacement of any weapon replaceable assembly (WRA) without calibration. The following units make up the control system:

- Hydro mechanical control unit, The HMU schedules fuel for combustion. It contains a high-pressure pump. The HMU has an actuator arm that positions the inlet guide vanes, the variable compressor vanes, and the anti-icing bleed and start valve. The HMU responds to engine inlet air temperature (T2), to compressor discharge air pressure (P3), and to a trim signal from the ECU/DEC to set fuel flow and variable vane positioning. It is designed to be adjusted at depot only. Adjustments to the HMU are safety wired to prevent adjustment at intermediate maintenance level,
- Electrical control unit (ECU) /Digital electronic control (DEC), Used for diagnostic testing of the engine electrical control system, interface with the test stand system and some sensors,
- Fuel boost pump. The fuel boost pump is an engine-mounted suction-type pump. It is not self priming.
- Fuel filter. The main parts of the fuel filter are: a disposable filter element, an impending bypass indicator button, a bypass relief valve, and an actual filter bypass sensor.
- Overspeed and drain valve which has three functions. First, it sends fuel through the main fuel manifold to the fuel injectors for starting, accelerating, and engine operation. Second, it purges the fuel injectors of fuel when the engine is shut down. It does this by allowing compressor discharge air (P3) to pass through the injectors. Third, it controls Np overspeed by cutting off engine fuel flow.
- Anti-icing bleed and start valve
- Ignition exciter. The ignition system is a noncontiguous, ac-powered, capacitor discharge type. It includes two igniter plugs, two electrical ignition leads, and an ignition exciter assembly. Power is supplied to the ignition exciter assembly by the engine's alternator during starting only.
- Np sensor: The power turbine rotor speed (Np) governing system compares the signal sent from the Np sensor with the Np selected by the operator. It varies fuel flow by actuating the torque motor in the Hydro mechanical control unit (HMU). Power turbine rotor speed is governed with $\pm 1\%$ of required rotor speed.

There are some engine control components, test cell systems and diagnostic equipment. Turbine gas temperature (TGT) limiting system. The TGT limiting system overrides the power turbine rotor speed governing system and the load-sharing system when TGT reaches 1542°F. It limits fuel flow to hold a maximum 1542°F TGT by actuating the torque motor in the HMU. The TGT limiting system is accurate to within $\pm 9^\circ\text{F}$. Np over speed protection system. The Np over speed protection system (fig. 12) receives a power turbine speed signal from the torque and over

speed sensor. When N_p exceeds $25,000 \pm 250$ rpm, output from the protection system activates a solenoid in the ODV. This shuts off fuel flow causing the engine to shut down. Load-sharing system. In twin-engine installations, the digital electronic controls (DEC) compare torque signals, for automatic load sharing. Hot Start Prevention (HSP). The HSP system prevents over temperature during engine start. The HSP system receives power turbine speed signal, gas generator speed signal, and turbine gas temperature (TGT). When N_p and N_g are below their respective hot start reference and turbine gas temperature (TGT) exceeds 1652°F and output from the HSP system activates a solenoid in the ODV. This shuts off fuel flow and causes the engine to shut down. Fault Indication. The DEC contains signal validation for selected input signals within the electrical control system. Signals are continuously validated when the engine is operating at flight idle and above. If a failure has occurred, the failed component or related circuit will be identified by a pre-selected fault code. It is possible to have more than one fault detected. Each code should be treated as an individual fault. It should be noted that the signal validation does not recognize aircraft instrument related failure. Fault codes will be displayed on the engine torque indicator.

Next the TW3-117M engine for the Mi-14 helicopters (Fig. 4) designed by S. Izotov team at Klimov Company. The turbine converts the potential energy of gas to mechanical work of the rotor that can be used by the consuming device. New materials have enforced some improvements to increase the gas temperature before the turbine without changing the geometry of the flow section, and the takeoff power. Further improvements are made to develop an advanced cooling system, use new materials including cermets, and reduce the weight of the turbine.



Fig. 4

Each type of engine has its own manual containing introductory information necessary to assure proper maintenance of the system. It includes all items having an approved mandatory component replacement interval and those items requiring Conditional inspections that shall be accomplished at the occurrence of an over limit situation. Conditional Inspection requirements include a brief description of what is to be performed and a reference to the manual or directive containing detailed requirements. Replacement items are indicated in unit hours, calendar time, cycles or event and are arranged by engine systems. All T700 engine hardware is tracked with Aeronautical Equipment Service Record. There are some cases like: salt water landing, hard landing, over-water hoisting operation, over-torque, overspeed, sudden stoppage, over temperature, oil pressure loss, engine operation limits exceeded, required conditional inspection in compliance with technical manual cards. The Chief Engineer established maintenance program for Naval Air Force which outlines the system of three levels of maintenance: organizational level (O-level), Intermediate (I-level) and depot-level (D-level) maintenance. The most interesting is the I-level maintenance. The objective of to enhance and to sustain the combat readiness and mission capability of support at the nearest location with the lowest practical resource expenditure. It consists of: maintenance on aeronautical components, calibration of designated equipment,

processing of components from non-mission capable planes, incorporation of technical directives, age exploration of a plane.

Correct and very precise diagnose and troubleshooting need technicians with years of experience on aircraft [2, 3]. Training is given with the emphasis on real-life incidents as a result of a human error and structure fatigue. The key is our ability to manage the volume and diversity of information required to keep engines running, and easy and fast access to that for those making repairs.

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