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Life Extension of Aircraft Components – An IAF Perspective

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ABSTRACT

Due to escalating cost of aircraft and feasibility for upgrading existing fleet with advance technology insertions at comparatively lesser cost, a trend is observed world over to extend the life of aircraft. IAF is no exception to this. Since OEMs have started demanding exhorbitant fees for giving life extension technology of their aircraft, a number of life extension projects have been undertaken by IAF with the help of various R&D, Public Sector, academic, certification and inspection agencies. These studies have highlighted the need to carry out basic and applied research for life extension of various aircraft components like airframe structures, aeroengine, undercarriage, canopies / perspex and rotables. A core group formed at the instance of IAF has identified these proposals under a project code named 'Project LIFEX'. It is the perception of IAF that adequate expertise is available within the country to meet all her life extension requirements.

INTRODUCTION

Indian Air Force has a large inventory of fighters, transport aircraft and helicopters of diverse origin. Most of the airborne equipment is manufactured ex-abroad with their life specified by manufacturers. Astronomical costs of new aviation equipment coupled with national constraints on resource have forced Indian Air Force to think in terms of delaying phasing out of their current inventory. Since main obsolescence of present weapon systems emanates from advances in avionics/armament technology and not due to any substantial advances in aerodynamic performance of aerial platform per se, a trend is observed world wide to carry out upgrade of existing aircraft and exploit them to their optimum potential. It is estimated that out of a population of 6000 old fighter aircraft the world over, nearly 3000 will have to be used with extended life span. Even developed countries have resorted to extension of very old aircraft. The longest serving aircraft operational with US Air Force are going to be the KC-135 in-flight refueling tankers, which with advanced technology insertions are slated to operate upto an incredible 80 years or more from original date of induction into service. Similarly B-52 Bombers are now cleared for flying upto 75 years of age after necessary checks and upgrade. The F-111s which were first introduced in United States during the year 1976 will probably get phased out in the US. However the Royal Australian Air Force is acquiring these aircraft and after upgrading, they are planning to use the aircraft up to year 2020. Canada, which acquired Sea King helicopters between 1963 to 1969, for roles that included anti sub-marine warfare, surface surveillance and Search and Rescue, is funding an upgrade programme so that these aircraft can be flown for many years. These helicopters have accumulated 10 000 to 12 000 flying hours. They have number of repair patches on structural members. During the planned upgrade, some of these structural members are envisaged to be replaced. These examples bring home the necessity for life extension as well as the direction in which the rest of the world is going. In the present scenario life extension has become an inescapable necessity for IAF also.

LIFE EXTENSION BY OEMS

It has been experienced that initial life assigned by the manufacturers is very conservative. As the aircraft is exploited in the country of origin as well as in the customer countries, the life of aircraft is further extended, based on the inputs received from all operators and analysis of this data. It is ironical that after receiving the exploitation data free of cost from customer countries, manufacturers not only benefit greatly by extending life of aircraft operated by their own country but also start demanding exhorbitant fees for passing on simple check lists to customers. To give some examples, we had to pay almost four million dollars for life extension of one of our transport aircraft from 6 to 8 years. Subsequently, for 9 to 12 years extension for the same aircraft, we paid another 5 million dollars. For extending life of one of our high performance reconnaissance aircraft from 1100 hours to 1500 hours and 15 years to 20 years, we have paid nearly 9 million dollars. Even for aeroengine of one of our helicopters we are paying 10, 000 dollars per 100 hours or one year extension per aeroengine. A sharp escalation was noticed when for one of our fighters, OEM demanded 30, 000 dollars per one year extension per aircraft which for a later generation aircraft was raised to an incredible 0.31 million dollars per one year per aircraft.

As a result of such exhorbitant fees demanded by OEMs and also due to the help received from our own R&D, public sector, academic, certification and inspection agencies, IAF has undertaken number of indigenous life extension projects for various fleet. These projects were of adhoc nature and carried out with our backs to the wall. However they have served dual purpose of giving the necessary confidence to IAF in indigenous capability for life extension and also highlighting various disciplines of life extension science where research work needs to be carried out at national level..

Airframe structures, aeroengine, undercarriage, canopy / perspex and rotables are the major aircraft components which need to be considered while granting extension for the aircraft. The specific requirements / criteria / expertise for life extension of these components are discussed in subsequent paragraphs with reference to some case studies.

AIRFRAME STRUCTURES

Airframe structure is the most critical component of aircraft since any inflight failure will have catastrophic consequences involving safety of the flight. The famous Aloha airlines accident in 1988; where at 24 000 feet, the aircrew suddenly heard loud sound and found that the cockpit door was gone and "blue sky" was seen in place of the first class cabin ceiling; was instrumental in refocusing the attention of aviation community on following critical issues:

(a) Assessment of structural condition and timely detection of structural problems.

(b) Fatigue testing and tear down inspection.

(c) Improved NDE technology.

In IAF, one of the fighter aircraft was given total life extension from 1 500 hours/15 years to 2 500 hours/25 years after a joint study by various R&D, PSU, academic, certification and inspection agencies with IAF specialists. The study involved collation and analysis of exploitation and defectation data, NDE checks of critical components, flight data records analysis and examination of rubber components and electrical cables as well as development of technology for second overhaul at 1 500 hours. During the study, it was found that repair schemes were provided by the manufacturers for cracks on certain structural members. From the cracks observed and repaired during overhaul, it was felt that Widespread Fatigue Damage (WFD), which encompasses Multiple Site Damage (MSD) and Multiple Element Damage (MED) may be seen on certain critical structural components in future. Computational modelling of central fuselage and outer wing where cracks were observed and which were highly stressed parts, was proposed as a method to study crack growth mechanics to decide on residual life as well as Time Before Overhaul (TBO). In yet one more case of our air defence fighter full scale fatigue testing of an airframe which has completed its present total technical life in terms of flying hours has been proposed after deciding on service loading from flight profiles flown by operational units and generating load distribution data through strain gauging, installation of on board data acquisition unit and fatigue meter. These are pioneer requirements of our country and considerable scientific work is required to be carried out, more so when the necessary design data is not provided by original manufacturers.

Non Destructive Evaluation has played significant role in all life extension studies undertaken so far. The conventional NDE techniques involving inspection with liquid penetrants, magnetic particles, X-rays, ultrasonic waves and eddy currents are getting refined with advanced techniques like Magneto-optic / Eddy Current Imager (MOI), Low Frequency Eddy Current Array (LFECA) and D-Sight Aircraft Inspection System (DAIS) for detection of corrosion and subsurface cracks without disassembly. Modern techniques like Infrared Imaging, Pyrometry, Shearography and Ultrasonic testing with Signal analysis are also used for composite structures, turbine blades, honey comb / sandwich structures and composite laminates of wing skin. These techniques will have to be mastered and adopted for life extension requirements of IAF in future.

AEROENGINES

Aeroengine components operate in more aggressive environment than airframe structure components. In addition to mechanical loads, these parts are subjected to thermal loads and hot gases. These components, therefore, accumulate fatigue at faster rate as a result of degradation due to erosion, corrosion, high cycle fatigue, low cycle fatigue, microstructure ageing, thermo-mechanical fatigue, oxidation, hot erosion, over-temperature and creep. This point was fully brought home to IAF when we experienced serious series of failures of compressor disc on one of our fighter aeroengines. Therefore, life extension of aeroengine is a more serious business.

A study is in hand at present to extend life of critical components like compressor rotor blades, turbine blades, compressor rotor disc, turbine disc, compressor rotor stround and turbine blades. The need was felt due to unexplained limitation on life of these components periodically imposed by manufacturers, large defectation and the enormous cost of replacement for these components. The fact that IAF had gained substantial experience and database on operation and overhaul of this engine gave the necessary confidence to undertake the study indigenously. This study has highlighted the importance of various issues connected with life extension of engine components such as cycle exchange ratio, preparation of accurate engineering drawings from samples, development of models and finite element analysis, residual stress measurement and so on. The need to have various test facilities like Cyclic Spin testing for rotor components, torsional fatigue test facilities for shafts, pressure test facilities for ducts and casings, vibration fatigue test facilities and thermal fatigue test facilities for blades and even a universal test bed facilities for the purpose of endurance testing for life extension has also been highlighted emphatically.

There is also need to carry out research in areas such as viscoelastic property evaluation, fracture mechanics study, computational methods and remaining life assessment of aeroengine components.

AIRCRAFT UNDERCARRIAGE

Aircraft undercarriage life is normally specified in terms of landings separately from airframe. It is a component of aircraft which undergoes heavy stress at the time of each landing. Due to its functional criticality, it is necessary to have adequate safety factor. It is found that normally compressive stress is induced on these components to counter the tensile loads experienced by the landing gears. With increased number of landings, fatigue is experienced on the surface layer. In one study carried out on undercarriages of one of the fighter aircraft, it was found that when compressive stress was measured in critically stressed areas on landing gears with different life the compressive stress reduced from 550 MPa for a new landing gear to 0 MPa for landing gear which had completed its overhaul life. More interestingly the compressive stress increased when it was measured at different depth. For a landing gear which had completed its overhaul life the compressive stress increased from 0 to original 550 MPa at a depth of 300 microns. Manufacturers had recommended a rejuvenation process during overhaul which included removal of fatigue layer of 300 microns from stress critical zones followed by low temperature tempering and pneumodynamic cold hardening to give further life. It was felt that if adequate reserve factor can be maintained after removal of another fatigue layer during second overhaul, life of undercarriage could be even extended beyond the total life recommended by manufacturers. This would be possible through stress calculations, fatigue testing of undercarriage and NDE checks to assess for structural integrity of the undercarriage. Life extension of undercarriage is critical for IAF due to the mismatch between total life of airframe and undercarriage for most of our fleet which has resulted in procurement of large number of undercarriages at enormous cost.

CANOPY AND PERSPEX

Canopies and perspex are normally given same life as the airframe. They are rejected during use 'on condition', depending on defects like silvering, discolouration, deep scratches, nicks, chips, cracking of sealing coumpound and lift of canopy under pressurisation beyond permissible limit. However IAF has experienced inflight failures of Canopies / Perspex resulting in catastrophic consequences. In one case the navigator was thrown out due to failure of a Perspex. Therefore structural integrity assessment of canopy assumes great significance. Of particular interest is the development of NDE technology which can detect the defects on Perspex, sealing compound as well as glued joint of canopy in time to avoid such inflight failures. Study of propagation of crack under simulated condition is also important to lay down safer criteria for extending further use of these components.

ROTABLES

All aircraft have many mechanical and avionic rotables which have their independent life. Mechanical rotables undergo overhaul at specified interval during which many parts are mandatorily replaced and others subjected to defectation and micrometry. These are replaced if found beyond specified tolerances. The life of the mechanical rotables can be unlimited since they are refurbished during overhaul. However the overhaul life is very critical for these rotables, since failure of items like fuel pump, hydraulic pump or control valves can have serious flight safety implications. In case of avionics rotables, certain components are likely to deteriorate with time and the performance of whole aggregate fall below the expected level. Thus each avionic rotable needs to be evaluated on merit and then its life fixed. A meticulous record of failures, MTBF, replacement of components etc will help in re-fixing life of rotables. However in aircraft where life of airframe is extended considerably, the avionics rotables usually undergo update with advance technology to improve their performance since obsolescence of rotables is generally faster as compared to airframe. Life extension of rotables, therefore, is not a major issue for IAF.

CONCLUSION

Life extension of aircraft components is of great relevance to IAF. It is the perception of IAF, that necessary expertise and infrastructure are available in the country to undertake indigenous life extension. Many studies undertaken jointly with other agencies have highlighted the need for further work in many disciplines of life extension science. In fact in a recent study number of proposals for basic and applied research for life extension have been jointly identified by a core group consisting of NAL, HAL, IGCAR, DMSRDE, NML, IISc, GTRE, CEMILAC and IAF representatives. Considering that aircrafts are basically weapon systems which are required to function at their optimum efficiency till they are in use, the task is not merely extending the life to guarantee safe performance but also to ensure that these weapon systems function like "Young Men" even in their old age in defence of the nation. Proposals prepared by the core group are being taken up with Government for approval under code name 'Project LIFEX'. Once approved the IAF expects the scientific community to play a pro-active role in execution of this project.