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THE PRINCIPLES OF FATIGUE APPROVAL FOR TRANSPORT AIRCRAFT AFTER ITS PRINCIPAL STRUCTURE ELEMENTS MODIFICATION

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Abstract

During modification aircraft structure is possible as new critical areas in redesigned structure parts, so too new spectrum aircraft applying, as a consequence - new load spectrum for initial structure parts. For compliance with airworthiness requirements, from the fatigue point of view, proposing to use bunch of final element analyses (linear static) together with engineer-analytical analyses. Effective stress concentration to have estimate through design, analyses, fatigue test of "design-like" samples with typical for this aircraft joints (bolts, rivets). The estimation of maintenance conditions aircrafts with redesigned structure concerning variable loads can perform by applying "Load Monitoring System" (LMS), based on FDR (Flight Data Recorder) information or special system.

Fig. 1. Real fatique tests of aircraft

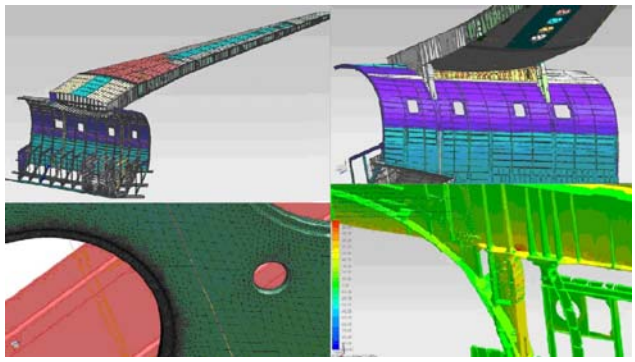

Fig. 2. CAE solid assembly wing

1 Introduction

Chief designer of the modified aircraft has a range of options evidence of conformity the certification basis of safety under the terms of strength in the long run. It can be performed by building and full-scale fatigue test additional aircraft with redesigned structure (Fig. 1) on the one hand, and a full-sized computing aided engineering (CAE) experiment (Fig. 2) on the other.

Building and testing an additional aircraft is the most accurate assessment of redesigned areas, but it is the most expensive and enduring way. Using a CAE model is much more quickly and cheaper implementation, but gives an unreliable results. Beriev aircraft company considers the optimum compromise, based on numerical analyses and limited sets of full-scale experiments. Each tool should be used strictly in that areas, where their validity can be checked by relatively simple tests.

2 Determination of the General stress-strain condition (SSC)

It is reasonable to calculate the general SSC with a solid CAE models. In contrast to traditionally used in the industry plate-rod models of General SSC (Fig. 3) solid model has full geometric accordance with a full-scale construction, which automatically means that the rigidity of the model and the structure is the same.

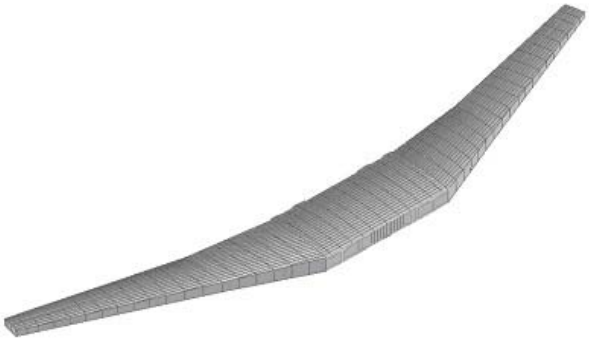

Fig. 3. Plate-rod model of general SSC

This circumstance allows to abandon the construction of the airframe fatigue tests, to consider it as a means of creating boundary conditions on the approach to the redesigned places, where the influence of the modification still no effect. Playback of boundary conditions with an acceptable accuracy can be obtained on the model. The standard of review are moving clouds checkpoint structures under load. No problems with accommodation on the outer surface of the aircraft reflectors modern contactless measurement systems movements, such as photometric measuring system V-STARS/M8 or laser tracker API Tracker 3. After application of the test (even minor) load to the unit becomes known deflection and angle of torsion. The same effect, applied to the estimated model (Fig. 4), will determine moving control points of the model. The comparison of the results will give rise either to believe calculation model (in the case of satisfactory convergence), or refine the design model to achieve an acceptable margin of error of simulation.

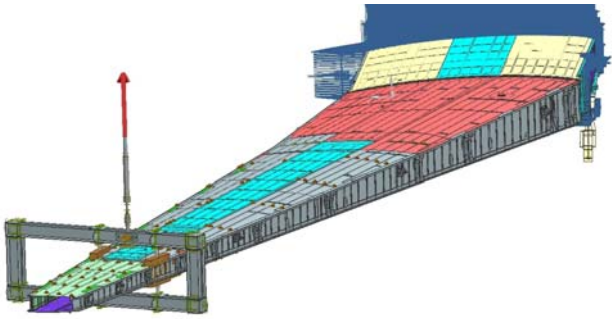

Fig. 4. Test force on the CAE model

Thus, the advantages of using a solid model to determine the general SSC modified design the following:

- the possibility of checking the serial aircraft;
- the use to further define the local SSC and durability, adjusted to add models fasteners.

3 Determination of the local stress-strain condition and durability

It can perform the analyses local SSC and durability, using the solid model of general SSC after its complexity. In critical areas instead of "gluing" details necessary to install the fasteners model [1]. There are estimated model of fasteners of different level of complexity. Beam model allow to define the integral power factors - shear strength along the length of the beam. Solid model allow to define zone contact, the contact pressure (Fig. 5).

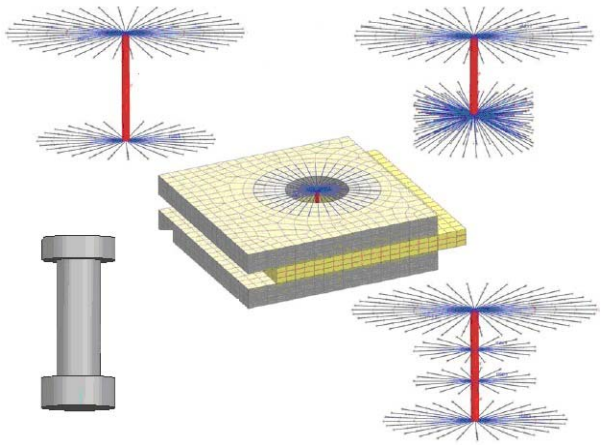

Fig. 5. Beamed and solid model of the fastener

However, the influence on the durability of factors such as the planting of bolt tightening torque nuts, type and method of setting rivets, technology of cutting holes, tall and ring the uneven distribution of stresses in the details, the friction between mating parts can be estimated by analyses only with the unacceptably large error.

All this does not give a reason to abandon the calculation at all. After calculation should be applied qualifying ratios. These factors take into account the difference between the results of analyses and tests of “design-like” samples. In the samples necessary to include the connections made by the same production, which was built (modified) aircraft. Example of the “design-like” sample of Be-200 aircraft is shown in figure 6.

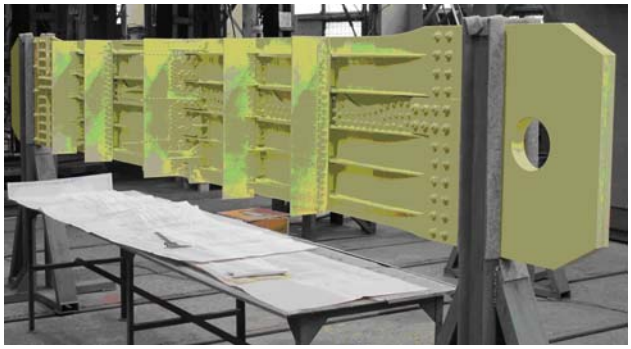

Fig. 6. “Design-like” sample

Such samples are tested for endurance tensile pulsating loads of the same level. The value of this experiment is that for a minor (in the scale of the unit) fragment completed:

- the analyses of the local SSC and durability by the same procedure as for the whole aircraft;
- the durability test such as connections, full-scale construction.

This allows as to compare the results of analyses of durability and results of tests of the sample (Fig. 7), and to check the correctness of analyses the entire model due to the experimental determination of the fatique-test construction zones with subsequent comparison with the estimated fatique.

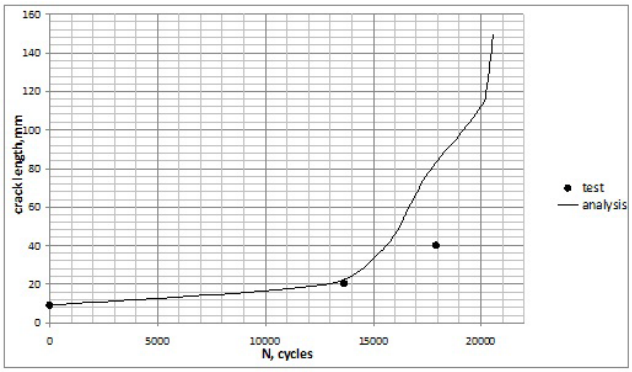

Fig. 7. Comparison of calculated and experimental crack growth rate

4 Maintenance conditions

The life test program for aircraft prototype was developed for some definite profiles of typical flight. Besides, it is possible that the plane before modifications have already been used. In this case, for invariant parts the load profiles will change.

According to the above, the relevant section of the aircraft maintenance Manual (MM) for modified plane should contain equivalents between different profiles of typical flights. An example of such entry from MM of multipurpose aircraft Be-200CHS [2] is shown in figure 8. This entry is in the section 005.10.06 of approved certification center "TSAGI - Test" and the Aviation Register of the Interstate Aviation Committee.

In arbitrary relation of flight hours between fire-fighting flights, cargo flight training flights and ferry flights, according to data provided by objective monitoring service, the serving out of assigned service life in flight hours must be calculated in accordance with the following formula:

$$0.077t_{ferry} + 0.056t_{cargo} + 0.447t_{training} + 1.549\,t_{fire\text{-}fighting\ w/o\ water\ scoop} + t_{fire\text{-}fighting} \leq 1452$$

where:

t_{ferry} – flight hours in ferry flights
t_{cargo} – flight hours in cargo flights
$t_{training}$ – flight hours in training flights
$t_{fire\text{-}fighting\ w/o\ water\ scoop}$ – flight hours in fire-fighting flights without water scooping
$t_{fire\text{-}fighting}$ – flight hours in fire-fighting flights.

Fig. 8. Entry from MM

The information about the operating conditions contains in a archive files from flight data recording system. This system is part of the standard design of the aircraft and installed on all planes, both experienced and serial. In particular, Beriev aircraft company has its own

software to determine the type of flight of the Be-200CHS aircraft during ground post-flight analysis. The type of flight determines automatically, and the result is entered in the MS Excel format, which is constantly updated.

5 The monitoring of the variable load

However, the transition to typical load spectrum requires a model, because FDR does not write load directly. The increment of overload correlates with increments of maneuvering loads well, but the average value of overload in "Y-direction" is always near to unity, while the load operation varies considerably depending on the weight of fuel, cargo, the provisions of mechanization.

Besides, the sampling frequency of FDR-sensors is sufficient to restore loads of functioning but it is insufficient to assess the dynamic loads. Therefore, in case of receiving data only from FDR, you can use only statistical dependences of loads from the intensity and time of oscillations of an overload in the centre of gravity of the aircraft on the flight conditions (Fig. 9).

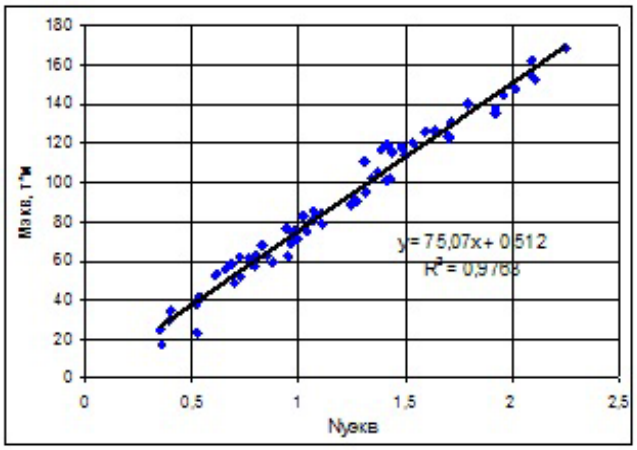

Fig. 9. Equivalent bending moment wing vs equivalent g-load

Of course, measuring loads and their comparison with the data from recording system should be made at the flight test stage. Traditionally deformation on experimental aircraft are measure by foil strain gauges, glued to the main power elements. But their guaranteed authentic indications of strain gages period is about 1 year. Further using is accompanied by an ageing of the adhesive layer, loss of elasticity, decrease the sensitivity of the strain gauge, as a consequence, the necessity of pregraduate. Therefore, the application of a test measurement technology for serial plane is impossible.

Currently, Beriev aircraft company is working on the assessment of the conditions of the modified aircraft through using the load monitoring systems (LMS). LMS provides an abbreviated system of onboard measurements, but instead of FDR it allows registration of load parameters, sensors of discovery and development of cracks by embedded software. Instead foil strain gauges assume the use the hull load cells, such as ST-350. LMS is able to grads them independently. A changing of bending moments of wing during refuelling can be used as calibration loads. The developer of the aircraft calculates the value of the landing bending moment depending on the weight of the fuel, the developer SMS puts this data into the system memory. For the root section of the wing of the plane Be-200CHS changing of the landing bending moment at a full load of fuel is 19 t*m. Maximum performance load is 250 t*m, so a range of the calibration load is 7.5%.

The landing values of load cells are set automatically from tabular data stored in memory LMS before the flight. Power on the hardware requires balancing channels before the beginning of work. Indications bridges are set to 0, although physically it is not - wing acts weight of fuel and construction, bottom panels are compressed, top ones are stretched. After the flight, each parameter is enforced in its landing value, from which the flight loading is calculated.

LMS also can diagnostic the channels operability automatically. It compares the measuremant results after landing with the tabular values of the landing moments for the current refills. When the error is not above a given value, LMS points a channel as efficient, otherwise - issues a diagnostic message about needing to replace and doesn't use a data from this channel in flight processing.

6. Conclusion and perspectives

The presented method of fatigue approval for redesigned structure based on complex data from ground fatigue test, flight test, analyses and maintenance data, without necessity of building additional aircraft for full-scale ground fatigue test.

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