JAR NPA 25C-271
FATIGUE SCATTER FACTORS

COMMENT DOCUMENT

INTRODUCTION

This NPA proposes an amendment to the JAR ACJ 25.571 paragraph 3.2, that is intended to clarify the guidelines for determining scatter factors for Safe Life items.

These proposals were developed in co-operation with the Federal Aviation Administration (FAA) of USA and the European and American aviation industry through the General Structures Harmonisation Working Group of the U.S. Aviation Rulemaking Advisory Committee (ARAC). Harmonisation of this guidance material will ensure that, in the future, similar scatter factors will be used to determine retirement lives of safe life structural components, as opposed to the dissimilar values of 3.0 and 5.0 currently used by US and European Authorities.

JUSTIFICATION

The common practice of today is to place significantly more emphasis on testing than on the basic fatigue design substantiation. This has led to the life of components being almost solely based upon the test demonstrated life divided by the factor (3.0 for FAA and 5.0 for JAA), irrespective of the design it was supporting. The danger with this custom is that the test article (often only one) may not actually be the "mean" of the population, but may have far better qualities than the population mean, and so give optimistic results.

Testing, however, does have great value in bringing to light many inherent design faults, or hot spots, that may have escaped the eye of the designers. History can surely validate this conclusion. To this end, the proposed ACJ separates the factors that affect fatigue life into what can best be addressed by testing and what can best be addressed in design. The first criteria to be addressed is whether the manufacturer has test and service experience of similar components, which initially differentiates between known and unknown fatigue behaviour.

The basic Scatter Factor, applicable to test results for components whose designs are similar to other components with test and in-service experience, has been agreed at a value of 3.0. This is to be applied to the test cycles. Parameters such as material variability and spectrum severity are best accounted for in design rather than in the testing of a limited number of specimens with the scatter in material fatigue properties being accounted for in either stress or life, whichever is more appropriate. Other parameters, such as the number of specimens to be tested and accuracy of test loading, can be applied directly to the Scatter Factor value of 3.0 as adjustments.

For those items that are basically new designs, the Scatter Factor applicable to test results must be adjusted to address all the relevant fatigue properties. The modified Scatter Factor, will have no maximum value, but will have a minimum value of 3.0 which may not be reduced.

Normally, for large aeroplanes, consideration of safe life structure is limited to the landing gears and their attachments since JAR 25.571 requires structure to be qualified damage tolerant, unless this is shown to be impractical. The minimum scatter factors proposed herein are applicable to landing gear structures. For application to other components, and in particular primary structure, other scatter factors may be appropriate depending on the required level of safety.

DISPOSITION OF COMMENTS

A large number of supportive comments were received indicating acceptance of the proposed amendments without change to the text. Just one significant comment was received and this was considered by the Structures Study Group (SSG) at its Meeting No. 97 held in Stockholm on 24-25 June 1997 and was resolved as follows:-

COMMENT: After comparison between the existing ACJ and the proposed ACJ, paragraph 3.4 (type design development and changes) in no mentionned in the proposed ACJ. We have been informed by our representative in the "general structures harmonisation working group" that in the agreed final draft issued by the working group, paragraph 3.4 was present and cited in this manner : "3.4. Type design developments and changes (no proposed changes)". In conclusion our comment is to correct this editorial error and to add this paragraph in this NPA.
SSG RESPONSE: Comment accepted. Paragraph 3.4 will be included in the final proposal.

Final Proposal:

By replacing the current JAR ACJ 25.571(a) paragraph 3.2 with the following text:

3.2 *Fatigue (Safe life) evaluation*

3.2.1 *General.* The evaluation of structure under the following fatigue (safe-life) strength evaluation methods is intended to ensure that catastrophic fatigue failure, as a result of the repeated loads of variable magnitude expected in service, will be avoided throughout the structure's operational life. Under these methods the fatigue life of the structure should be determined. The evaluation should include the following:

a. Estimating, or measuring the expected loading spectra for the structure;

b. Conducting a structural analysis including consideration of the stress concentration effects;

c. Performing fatigue testing of structure which cannot be related to a test background to establish response to the typical loading spectrum expected in service;

d. Determining reliable replacement times by interpreting the loading history, variable load analyses, fatigue test data, service experience, and fatigue analysis;

e. Evaluating the possibility of fatigue initiation from sources such as corrosion, stress corrosion, disbonding, accidental damage and manufacturing defects based on a review of the design, quality control and past service experience; and

f. Providing necessary maintenance programmes and replacement times to the operators. The maintenance programme should be included in Instructions for Continued Airworthiness in accordance with JAR 25.1529.

3.2.2 *Scatter Factor for Safe-Life Determination*. In the interpretation of fatigue analyses and test data, the effect of variability should, under JAR 25.571(c), be accounted for by an appropriate scatter factor. In this process it is appropriate that the applicant justify the scatter factor chosen for any safe-life part. The following guidance is provided (see Figure 1):

a. The base scatter factors applicable to test results are: BSF_1= 3.0, and BSF_2= (see paragraph 3.2.2(e) of this ACJ). If the applicant can meet the requirements of 3.2.2(c) of this ACJ he may use BSF_1 or, at his option, BSF_2.

b. The base scatter factor, BSF_1, is associated with test results of one representative test specimen.

c. *Justification for use of BSF_1.* BSF_1 may only be used if the following criteria are met:

(i) *Understanding of load paths and failure modes.* Service and test experience of similar in-service components that were designed using similar design criteria and methods should demonstrate that the load paths and potential failure modes of the components are well understood.

(ii) *Control of design, material, and manufacturing process quality.* The applicant should demonstrate that his quality system (e.g. design, process control, and material standards) ensures the scatter in fatigue properties is controlled, and that the design of the fatigue critical areas of the part account for the material scatter.

(iii) *Representativeness of the test specimen.*

(A) The test article should be full scale (component or sub-component) and represent that portion of the production aircraft requiring test. All differences between the test article and production article should be accounted for either by analysis supported by test evidence or by testing itself.

(B) Construction details, such as bracket attachments, clips, etc., should he accounted for, even though the items themselves may be non-load bearing.

(C) Points of load application and reaction should accurately reflect those of the aircraft, ensure correct behaviour of the test article, and guard against uncharacteristic failures.

(D) Systems used to protect the structure against environmental degradation can have a negative effect on fatigue life and therefore should be included as part of the test article.

d. *Adjustments to base scatter factor BSF_1.* Having satisfied the criteria of paragraph 3.2.2(c), justifying the use of BSF_1, the base value of 3.0 should be adjusted to account for the following considerations, as necessary, where not wholly taken into account by design analysis. As a result of the adjustments, the final scatter factor may be less than, equal to, or greater than 3.0.

(i) *Material fatigue scatter.* Material properties should be investigated up to a 99% probability of survival and a 95% level of confidence.

(ii) *Spectrum severity.* Test load spectrum should be derived based on a spectrum sensitive analysis accounting for variations in both utilisation (i.e. aircraft weight, cg etc.) and occurrences / size of loads. The test loads spectrum applied to the structure should be demonstrated to be conservative when compared to the usage expected in service.

(iii) *Number of representative test specimens.* Well established statistical methods should be used that associate the number of items tested with the distribution chosen, to obtain an adjustment to the base scatter factor.

e. If the applicant cannot satisfy the intent of all of paragraph 3.2.2(c) of this ACJ, BSF_2 should be used.

(i) The applicant should propose scatter factor BSF_2 based on careful consideration of the following issues: the required level of safety, the number of representative test specimens, how representative the test is, expected fatigue scatter, type of repeated load test, the accuracy of the test loads spectrum, spectrum severity, and the expected service environmental conditions.

(ii) In no case should the value of BSF_2 be less than 3.0.

f. *Resolution of test loadings to actual loadings.* The applicant may use a number of different approaches to reduce both the number of load cycles and number of test set-ups required. Due to the modifications to the flight-by-flight loading sequence, the applicant should propose either analytical or empirical approaches to quantify an adjustment to the number of test cycles which represents the difference between the test spectrum and assumed flight-by-flight spectrum. In addition, an adjustment to the number of test cycles may be justified by raising or lowering the test load levels as long as appropriate data support the applicant's position. Other effects to be considered are different failure locations, different response to fretting conditions, temperature effects, etc. The analytical approach should use well established methods or be supported by test evidence.

3.3 *Replacement times.* (no proposed changes)

3.4 *Type Design Developments and Changes* (no proposed changes)

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