

(1) *Definitions*

The following terms are defined for the purposes of interpreting JAR-E 840 and this ACJ.

- (a) Rotor: Individual stage of a fan, compressor or turbine assembly (some assemblies may consist of only one stage).
- (b) Sample Rotor: A test article or assembly including, where appropriate, coverplates, spacers, etc. that is representative of the standard to be certified and for which the material properties and dimensions are known.
- (c) Maximum permissible rotor speed associated with a rating: the maximum of all approved speeds, including transients, for the relevant rating. When applicable, this includes the Maximum Engine Overspeed which is an approved 20-second transient.

(2) *General*

- (a) The demonstration of compliance with the safety objectives of JARE 840(a) and (d) may be made separately or be combined, as described in this advisory material.
- (b) JAR-E 840(a) and (d) allow various means of compliance ("tests, analysis or combination thereof) in order to meet the objective identified therein. It is the applicant's responsibility to propose the appropriate means of compliance, in accordance with the guidelines defined in this ACJ.
- (c) Any analysis approach allowed under JAR-E 840 should be defined and validated before usage.
- (d) The applicant should submit to the authority the appropriate analysis to determine which of the conditions in JAR-E 840 b)(1) through (b)(4) is the most critical for each individual rotor stage with respect to the requirements of JAR-E 840(a). A similar analysis should be submitted with respect to the requirements of JAR-E 840(d).

Where the peak overspeed is limited by deliberate blade shedding :

- (i) the factors of JAR-E 840(b)(3) and (b)(4) nevertheless apply to a fully bladed rotor at the shedding speed, and
- (ii) the analysis to determine the most critical speed with respect to rotor integrity should consider blade shedding throughout the flight envelope. Consideration should be given to the blade failure speed taking into account the effects of tolerances, temperature and material property variations of the blades together with the most adverse combination of the effects of tolerances and material properties on the integrity of the rotor. Consequently the most critical speed with respect to rotor integrity might not be coincident with the highest achievable blade shedding speed.
- (e) While considering the most adverse combination of dimensional tolerances and material properties, as required in JAR-E 840(a) and (d), the applicant should also consider the tolerances and material properties of blades, overspeed limiter etc. adversely influencing stress levels in the rotor. The material properties assumptions, including undetectable defects, used for lifing calculations should also be considered for the purpose of this requirement.
- (f) Failure conditions which are of a sudden transient nature (reference JAR-E 840(a) & (d)) are typified by loss of load failures, i.e. characterised by high rates of acceleration and deceleration with no dwell period at the highest overspeed attained. J

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[ The applicant should also examine all possible failure conditions to determine if any case exists which would result in a dwell period at speeds close to that of the transient short duration failure condition. If such a case exists, the applicant should determine which condition is the most *critical* with respect to rotor integrity.

(g) The appropriate percentage speed factor of JAR-E 840(b) should be applied after making the necessary speed adjustments for temperatures, material properties, tolerance effects, etc. The necessary speed adjustments for temperature and material properties will normally be established on the basis of appropriate ratios of material properties.

(h) The consequences of rotor growth sufficient to cause significant contact or displacement between engine components should be assessed to determine that the requirements of JAR-E 840(d)(1) can be met.

(i) When determining compliance with the requirements of JAR-E 840(d)(2) the applicant should consider whether or not the rotor would exhibit any condition that would be likely to prevent the safe operation of the engine for a period of time that could occur in service following any failure or combination of failures considered under JAR-E 840(b)(3) or (b)(4). This period of time might be equal to that required to recognise the event and shut the engine down, or to that required for continued safe flight and landing. The length of time might also depend upon the operational instructions for an overspeed event.

U) Where a number of rotors are of similar design, are made of materials to the same specification and are subjected to similar stress conditions, temperature levels and gradients, it is permissible for compliance with JAR-E 840 (a) to test only the most critical rotor, with respect to burst. This would require determination of the burst speed for each rotor in order to select the most critical which is assumed to have the smaller margin to burst above the speeds specified in JAR-E 840(b).

The most adverse combination of temperatures and temperature gradients which is possible throughout the entire operating envelope may vary for individual rotors in an assembly.

The most critical rotor with respect to burst might not be the most critical with respect to growth. Consideration should be given to the components surrounding each rotor in order to determine the most critical rotor with respect to growth for compliance with JAR-E 840(d).

(k) Appropriate tests or analysis based on tests should establish the burst speed of each fan, compressor, and turbine rotor design in relation to the most critical condition prescribed in JAR-E 840(b) and this should be reported in the certification documentation. These burst speeds should be based on the most adverse combination of dimensional tolerances and material properties.

(l) For a multi stage rotor in which the rotors do not meet the conditions of similarity as described in paragraph (2)(j) above, the compliance of each rotor stage with JAR-E 840 should be substantiated using representative test data.

(3) *Acceptable means of compliance may include*

(a) Testing a sample rotor on a rig or engine at the conditions necessary to demonstrate that a minimum strength rotor would meet the requirements of JAR-E 840.

(b) Where the conditions of JAR-E 840(b)(1) or (b)(2) are the most critical, testing a sample rotor for the required period of time in an engine at not less than 96% of the speed necessary to demonstrate that a minimum strength rotor would meet the requirements of JAR-E 840 provided that this resultant reduced test condition is not less severe than that required to demonstrate compliance with JAR-E 840(b)(3) and (b)(4) and, it is shown from a validated method of burst prediction that burst would not have occurred at the conditions of JAR-E 840(b) (1) or (b)(2).]

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[ (c) An analytical modeling method based on representative test data may be acceptable provided that :

- (i) the model has been validated by comparison with results from specimen and rotor tests and
- (ii) its use is limited to rotors with material, geometry, stress, and temperature conditions encompassed by those used to construct the model and
- (iii) the predictions show that the certification standard rotor is not more critical, with respect to burst and growth, than any similar rotor for which substantiation has been demonstrated both by rotor test and model prediction.

(d) Any test may be continued to rotor burst after the required time duration by increasing the speed until the rotor bursts. If the applicant chooses this method, then it should be shown that :

(i) The sample rotor was initially run at conditions not less severe than those required for compliance with JAR-E 840(a), and

(ii) JAR-E 840(d) can be complied with using an approved analytical modeling method.

(4) *Factors To Be Considered When Determining Test Conditions*

(a) *Temperature*

The rotor temperatures required by JAR-E 840(b) are:

(i) for JAR-E 840(b)(1) and (b)(2) the material temperatures and temperature gradients equal to the most adverse which could be achieved when operating in the engine at the required rating condition.

(ii) for JAR-E 840(b)(3) and (b)(4) the material temperatures and temperature gradients equal to the most adverse which could be achieved when operating in the engine at the required rating condition immediately prior to the failure(s).

These temperatures and temperature gradients should be established by temperature surveys on an engine, or derived by a validated analysis. Adjustments of test speed or blade mass or both should be applied to compensate for any deviation from the required temperatures and temperature gradients.

(b) *Sample Rotor Material Properties*

Material properties of the sample rotor may be determined from attached test rings/bars when the correlation of their properties has been established by a validated method using coupons obtained from forgings/castings of the type to be approved.

When attached test rings/bars are not available to determine the material properties of the sample rotor, a value for the material properties may be established by assuming that the sample rotor possesses material properties equal to known average properties of similar rotors from the same manufacturing process lot if it can be shown that the assumption is valid within acceptable confidence limits.

(c) *Dimensional tolerances*

Analysis of dimensional tolerances should be made to identify the most adverse combination with respect to the integrity of the rotors. ]

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### [ (5) *Failure Cases*

In order to determine the highest overspeed resulting from a loss of load to be considered under JAR-E 840(c), it will be necessary to consider, for possible failure locations, such factors as system inertia, available gas energy, whether the rotor is held in plane, overspeed protection devices, etc. ]

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