# Decision Method for Selecting a Speed Margin to Protect Against Hazardous Rotor Growth during Transient Overspeed Conditions

## *Application:*

This guidance material applies to the determination of an acceptable rotor growth according to 14CFR Part 33.27/CS-E 840 Section (d).

## *Definitions:*

Suitable (or Reasonable) Margin: These are terms found within the current body of the regulations which form the basis of the selection of the terminology, “suitable speed margin.” An example can be found in 14CFR Part 33.83(d)/CS-E 650(f): “The suitability of these stress margins…”

Suitable Speed Margin: The speed margin necessary to reliably account for the uncertainties associated with transient overspeed and rotor growth analyses. Having a suitable speed margin means the analyses are capable of calculating rotor growth such that the most limiting rotor with respect to growth meets acceptable growth of 14CFR Part 33.27/CS-E 840 Section (d).

## *Suitable Speed Margin for Rotor Growth Assessments:*

The sophistication and conservatism included within transient overspeed and rotor growth assessments can vary from applicant to applicant. Applicants which use more conservative analytical methods have more inherent speed margin capability (i.e., additional margin to compensate for inaccuracies in the assessment method or modeling assumptions) than those applicants who use less conservative analytical methods. To account for the relative conservatism of the analysis methods from applicant to applicant and to better reflect a more consistent application of requirements across the industry, a suitable speed margin is established depending on the conservatisms embedded within an applicant’s methodology and the level of verification of the associated modelling assumptions. The suitable speed margin is established as being either 2.5% or 5% of the maximum transient overspeed condition. The selection of the appropriate suitable speed margin for an applicant is provided in the next section.

It is considered appropriate to have different assessment speeds for disk burst in 14CFR Part 33.27/CS-E 840 Section (b)(3) and acceptable growth in Section (d) because:

- If the same assessment speed was used, the requirements of Section (d)(2) “Following an overspeed event and after continued operation, the rotor may not exhibit conditions such as cracking or distortion which preclude continued safe operation”, mean that the disk burst criterion in section (b)(3) is automatically satisfied and effectively becomes redundant.

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- The principal consideration in the acceptable growth calculations is considered to be blade release, which although likely to lead to Hazardous Engine Effects, will have lower associated energy than a disk burst and therefore could be considered to require less additional margin in the assessment beyond the use of minimum material properties and assuming the most adverse flight envelope conditions.

## *Selection of a Suitable Speed Margin:*

In order to use 102.5% (i.e., a 2.5% speed margin) of the maximum speed resulting from a component or system failure as described in section (b)(3) of CS-E 840 and 14CFR Part 33.27 for the acceptable growth assessment, an applicant must provide evidence from engine or test experience of the assumptions made relating to:

- Compressor surge recovery following shaft failure and the combustor blow down pressure profile as a function of time
- The axial position of the turbine as a function of time if the axial restraint is lost following shaft failure
- Blade spragging/shedding behaviour (high circumferential loads from heavy blade shroud-casing rubs that can cause blade roots to be torn out of the disks at a lower speed than predicted by standard disk growth calculations)
- Frictional contact that absorbs energy and reduces the terminal speed, including the coefficients of friction and contact loads
- The effects of any control system interactions including protection systems and their operating tolerances
- The effect of tolerances of the engine parts and engine operating conditions on the terminal speed such as those arising from turbine flow capacities as the turbine speed increases and blade weights that have a significant effect on the terminal speed.
- The engine operating conditions are those which occur within the certified engine flight envelope and are not flight conditions which would violate the physics of engine operation such as combining the attributes of widely disparate flight conditions into a single flight condition for overspeed assessment.

In addition, the “minimum specification rotor” mentioned in 33.27 (a)(1)/CS-E 840 (a) includes:

- The most adverse geometry for overspeed capability as defined by the drawing tolerances
- Minimum material properties allowed by the type design
- Maximum (+3$\sigma$ with 95% confidence) blade set weight
- Material behavior at large strains, including:
    - Loading rate effects on material strength for alloys that display strain bursts (an inhomogeneous material deformation such as the Portevin-Le Chatelier effect)

- Reduced material ductility due to surface treatments such as shot peening that can influence the rotor burst speed

For analytical methods which do not meet all of the above attributes, a speed margin of 5% (i.e., 105% of the section (b)(3) max speed) is required.

August 5, 2019

Dr. Michael Romanowski
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Dr. Romanowski:

On behalf of the Aerospace Industries Association (AIA), and the AIA Overspeed Working Group, please see the attached white paper, in response to a request from the FAA (attached) to evaluate an acceptable growth during overspeed criteria.

The team's intent with this white paper is to provide guidance to applicants when showing compliance to 14 CFR Part 33, Section 33.27(d), when evaluating acceptable growth during an overspeed event. The team believes the material is suitable for use by regulatory agencies internally and as the basis for formal advisory material.

Although the material was prepared at the specific request of FAA, EASA and Transport Canada have been active members of the team. If you are in agreement, we would request that the FAA forward this to EASA and Transport Canada for review.

The principal team members that developed this guidance are:

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Please let us know if you have any questions or comments,

Leslie Riegle
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November 17, 2016

Aerospace Industries Association
Attn: Ali Bahrami, Vice President, Civil Aviation
1000 Wilson Boulevard, Suite 1700
Arlington, VA 22209-3928

Dear Mr. Bahrami:

The FAA would like to request the Aerospace Industries Association expand the charter of the advisory group on overspeed standards related to shaft failures and loss of load. Expansion of this charter would include a review of the rotor growth assessment requirements specified in § 33.27(d) to determine whether changes are necessary.

This request is the direct result of a difference, discovered while working on an engine program, between the FAA's interpretation of rotor growth assessment requirements and the European Aviation Safety Agency. Specifically, the original equipment manufacturer was assessing the impact of rotor growth at 100 percent of the maximum transient rotor overspeed due to a loss of load event, rather than the rotor growth assessment at 105 percent of that rotor overspeed specified in § 32.27(b)(3) requirements.

We would appreciate your consideration of our request to expand the advisory group charter. Please send any comments or questions to Tim Mouzakis, ANE-111, via email at Timoleon.Mouzakis@faa.gov or by telephone at (781) 238-7114. We look forward to hearing from you soon.

Sincerely,

A C. Mollica

Ann C. Mollica
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Cc: Tim Mouzakis (ANE-111)
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