Proposed Equivalent Safety Finding on CS-E 840/850 – Rotor Integrity/Shafts
EASA

*Please insert page number as well as paragraph of the document commented on.

Commentor:	UK CAA
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Paragraph No: Statement of Issue

Comment: We do not have any knowledge of the precise arrangement being discussed in this application, and so can only make general comments on this proposal based on the limited information presented in the text.

AMC 850 (3) material makes it clear that use of the provisions of CS-E 850(a) (3) should be **strictly limited**. The rule was developed to address certain limited areas of a shafting system where fail safe design may not be possible for a conventional design. This should not be the case for an HP system. Applying the provisions to the complete torque carrying area as proposed by the applicant is well beyond this intent.

In this case the geometry under consideration appears to be similar to that used in previous designs by the applicant, since it is proposed to use service experience as evidence of satisfactory design. It is not clear from the text if any of the earlier variants being used to supply service evidence were certified to the 850 regulation as currently written or not. If they were, then the principle of satisfying the current rule with the design layout under consideration is already established, and it is proposed that EASA seek compliance with the regulation as contained in CS-E.

Author's Response: Not agreed.

EASA concurs with the commenter regarding the development and intent of the rule. EASA believes however that the previous principle of compliance is no longer viable, as described below, and the application of the rule as proposed here is reasonable for the HP shaft for this engine.

"Fail safe" was always considered to be a characteristic inherent in the design of an HP rotor shaft due to the rapid surge and sustained stall of the HP compressor following a sudden loss of drive/rear location. Consequently terminal speeds resulting from loss of load on the HP turbine was never previously found to be the defining terminal speed for the purposes of rotor integrity demonstration. This was primarily a theoretical argument supported by limited historic experience and due to the high reliability of more modern designs there is no recent in-service experience to support the claim. The assumption was always convenient however from the point of view of compliance in that recourse to CS-E 850(a)(3) was never required (which would have introduced the problem of applying the "certain elements" approach).

The applicant applied this established understanding and the associated design practices in the design of this engine, thus sizing the turbine disc accordingly. Subsequently service experience of other engine types (not HP shaft however) revealed that new factors now have a bearing on the previous assumption. A combination of improved compressor mechanical durability and improved aerodynamic efficiency have been found to enable a potential flow recovery during compressor rundown that may be sufficient to accelerate a dislocated turbine disc. The applicant has shown that this may lead to turbine disc burst under certain conditions. The applicant was requested to propose design solutions but argued these were impracticable based on the scale of change required and the loss of design pedigree. The compliance option was thus to consider paragraph CS-E 850(a)(3) for the HP shaft.

Because of the difficulty of applying the “certain elements” approach to effectively a single element shaft a careful re-examination of the motivation and intent of the current shaft/rotor integrity rules has been carried out. This has concluded that the grounds on which extremely remote reliability claims were strictly limited for long shafts, i.e. that the complexity of the environment renders prediction of failure rate unreliable, are not applicable for the HP shaft. The service experience of the applicant and also on modern engines generally was considered to support this conclusion.

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Paragraph No: Applicant’s proposal

Comment: The applicant proposes to substantiate an Extremely Remote probability of failure based upon service experience. EASA should seek a high level of confidence in any statements made, since they address a hazardous failure mode. It should be noted that, for high levels (90%+) of confidence to be claimed, several hundred million hours of failure free operation would need to be demonstrated, and many designs do not have sufficient experience to claim this.

Author’s Response: Noted.

The nature of the industry is such that quantitative proof of the extreme levels reliability that are demanded can rarely be achieved. The establishment of Extremely Remote for engine component reliability has therefore always entailed a degree of engineering judgement, for instance where the application of specific disciplines for manufacturing, service management and engineering control are relied upon to ensure Extremely Remote probability of failure in the case of a turbine or compressor disc. Such approaches were evolved in an empirical way on the basis of perceived good service experience and have been vindicated by their subsequent effectiveness. The same is true for the HP shaft.

While the HP shaft fundamental design can claim in excess of 200 million hours of failure free operation this does not fully meet 90% confidence, it is however comparable with other critical parts, and the HP shaft is also supported by the same critical part disciplines that will minimise the risk of primary failure.

Furthermore a factor which has not been included is the risk of failure actually causing hazardous effects which, while hard to quantify, would probably reduce the calculated risk of hazardous effects by at least an order of magnitude.

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Paragraph No: Applicant position

Comment: Justification: The applicant claims that complex environments are largely not applicable to the HP shaft. AMC 850 (a) (3) however lists typical failure modes to be considered which could lead to shafting failure, based on experience. Most of these are as applicable to an HP system as any other, and the argument that they are “largely not applicable “ to the HP shaft system should not be accepted by EASA..

Author’s Response: Partially agreed.

The likelihood of each of the failure modes outlined in AMC 850 (a) (3) has each been formally assessed, as required by EASA, and reported for the case of the HP shaft by the applicant and only on the basis of this assessment have judgements been agreed or otherwise by EASA.

The list of threats provided by AMC 850 (a) (3) was based on failure seen on classic shaft designs. The HP shaft design in question differs significantly from a classic shaft (for example it features no bearings, no oil system components, has high stiffness and significant clearance to other shafts). It is inevitable therefore that some threats associated with features of a classic shaft, that are not features of the HP shaft, will not be applicable to the HP shaft.

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Paragraph No: -

Comment: As a general comment on ESFs and Special conditions which EASA issue for consultation, it would be helpful to know what amendment level of the Certification Specification is being used as the certification basis for the product.
This is not quoted in the ESF raised.

Author’s Response: Noted.

CS-E Amendment 2 is applicable in this case.