

FEDERAL AVIATION ADMINISTRATION'S
APPROACH TO ENGINE ROTOR INTEGRITY

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INTRODUCTION

Close review of the record shows that aircraft engine failures are not a major contributor to commercial aircraft accidents today. This position has been arrived at by the concerted effort and resources of the entire industry, and the results are such that everyone in the industry can rightly have a feeling of pride and a sense of accomplishment. That is not to say, however, that now is the time to relax the effort. Engine problems, while not major, do occur occasionally. These include engine surge at or soon after rotation on takeoff, the need for engine shutdown after ingesting birds and an occasional rotor disk failure.

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Even though engine failures are not a major contributor to airline accidents, the FAA is intensely interested in engine rotor integrity. This interest is demonstrated by the fact that there are several active programs under FAA sponsorship relating to this subject. Of particular interest to the FAA is the NASA Rotor Burst Protection Program. It is hoped that this program will result in a significant reduction in engine rotor failures.

The approach of the FAA to the protection of aircraft from uncontained engine rotor fragments is threefold. First, design and test requirements are imposed on engines for the purpose of ensuring to the maximum extent practicable the integrity of the engine rotor. Second, because the possibility always exists that the rotor will fail, design and test requirements are imposed on the engine to ensure some containment capability. Finally, because complete containment of all high energy fragments has been considered impracticable up to now, design requirements are imposed on transport type aircraft to minimize the hazard to the aircraft from uncontained engine rotor fragments.

ENGINE DESIGN AND TEST REQUIREMENTS

The engine design and test requirements are covered in the United States Code of Federal Regulations, Title 14, Aeronautics and Space,

Part 33, Airworthiness Standards; Aircraft Engines. There are several sections of these Airworthiness Standards that contribute to rotor integrity.

Section 33.14, entitled "Start-Stop Cyclic Stress (Low-cycle Fatigue)," presents the low-cycle fatigue requirements. At the present time the engine manufacturer is required by this section to determine the predicted safe life of each rotor disk and spacer in the engine. An initial service life is then established at one-third of the predicted safe life. The section also describes the procedure to be used if it is desired to extend the initial service life to some higher value. To do so, three disks and spacers of each part number that have reached the initial life in service must undergo an additional number of cycles equal to at least twice the number of cycles comprising the increase in the limit desired.

Section 33.27, entitled "Turbine, Compressor, and Turbo-Supercharger Rotors," presents the overspeed design and test requirements for these engine components. The overspeed required is 120 percent of the maximum limiting rpm if the rotor is tested on a rig, or 115 percent of its maximum limiting rpm if it is tested on the engine.

Section 33.62, entitled "Stress Analysis," requires that a stress analysis be performed on each turbine engine showing the design safety margin of each turbine engine rotor disk, spacer and rotor shaft.

Section 33.75, entitled "Safety Analysis," requires it to be shown by analysis that any probable malfunction or any probable single or multiple failure, or any probable improper operation will not cause the engine to:

- (a) catch fire;
- (b) burst (penetrate its case);
- (c) generate loads greater than those specified in §33.23; or
- (d) lose the capability of being shutdown.

Section 33.83, entitled "Vibration Test," requires that each engine must undergo a vibration survey to determine the vibration stresses. This section further requires that these stresses may not exceed the endurance limit stress of the material from which these parts are made.

CONTAINMENT REQUIREMENTS

Section 33.19, entitled "Durability" requires that "the design of the compressor and turbine rotor cases must provide for the containment of damage from rotor blade failure." Traditionally, the demonstration

of compliance with this requirement was accomplished in an evacuated spin pit. In October 1974, as part of a major revision of the engine airworthiness requirements, a change was made to require that demonstration of compliance with the containment requirements be accomplished on an engine.

AIRCRAFT DESIGN REQUIREMENTS

The requirements relating to transport type aircraft are covered in the United States Code of Federal Regulations, Title 14, Aeronautics and Space, Part 25, Airworthiness Standards; Transport Category Airplanes. Section 25.903(d)(1) reads: "For turbine engine installations design precautions must be taken to minimize the hazards to the airplane in the event of an engine rotor failure...."

This requirement is very general and gives no guidance on what to do to comply with the requirement. In such cases, the general practice is for FAA Headquarters to prepare and distribute what is called "guidance material" describing one or more ways of complying with a general requirement. Guidance material has been distributed for this requirement and includes such considerations as:

1. Location of the engines relative to each other and to critical portions and systems of the airplane.

2. Location and separation of critical components and redundant systems.

3. The strategic location of protective armor and deflector shields.

More details on what is actually done in any given airplane to meet the FAR 25.903(d)(1) requirement can best be obtained from the airplane manufacturer.

CURRENT FAA ACTIVITY

The aircraft industry is not a static industry. Consequently, the FAA regulations are not static. We have underway, therefore, study contracts that will help improve the regulations. One of these contracts is with an engine company and will determine the weight penalty for two different levels of increased containment. The other contract is with an airplane company and is studying the penalties associated with protecting critical structure and systems, the passenger cabin and the flight deck by strategic location of armor shields or deflector plates. Results of these two contracts are not yet available, but they will be used to propose revisions to the regulations as appropriate.

CONCLUSION

The FAA has watched the NASA Rotor Burst Protection Program with interest for several years. In fact, the two contracts mentioned above require the contractor to evaluate and use to the degree practicable all the reports published under the Rotor Burst Protection Program. It is our hope that this workshop will somehow provide what is needed to make a significant reduction in uncontained rotor failures.

DISCUSSION

J.C. Wallin, British Aircraft Corporation

I am interested in your comments on the studies that you had done on looking at the weight penalty for increased levels of containment on the engine as against improved methods of protection on the airframe. In the UK, we were getting together a similar study with the CAA and Rolls Royce to put to our government for some funding. I'd be interested to know, how soon you expect to get some results from your present study, whether in fact you already have some results which are leading you to conclusions, and whether it is worthwhile trying to press my government for additional funding to do a study of this sort. Intuitively, I think we believe that the aircraft protective methods are likely (in the majority of the present day aircraft configurations) to result in the lightest form for improving protection. We think that increased protection in the engine is likely to lead to weight increases which are unjustified, on the whole, on typical North American subsonic configurations. I think perhaps in the case of special configurations, particularly of the Concorde kind, increased containment on the engine might be the lightest way of doing it. We had to add on something like about a thousand pounds of additional weight on the Concorde to look after non-containment problems.

A.K. Forney, FAA

Well, we should have reports available for distribution within three to six months on both of our projects. I'm not sure of the exact schedule. For one of them we do have the draft final report for review now, so the report should be available fairly soon. Our objective is the same as yours, it's to determine the trade-offs between increased containment on the engine and doing it on the airplane. And we just had no studies in hand that gave us any indication at all; that was the purpose of undertaking them. We confined the study to a wide-bodied jet with a high bypass ratio engine. You are fully aware of the current status of SST activity in the United States so we did not address that question. The draft report that I've seen (which was from the airframe study) does recommend continued effort. The results of the work to date uncovered fruitful areas for further work. So I would heartily endorse your continuing to try to press for effort in that area because, apparently it would be fruitful. Does that answer all your questions?

Guy Mangano, Naval Air Propulsion Test Center

I'd like to comment on Ken's statements regarding the conclusions that we drew in the cited report.

It's a matter of interpretation. The report means to imply that of all the different types of fragments generated at burst (disk and fan blade fragments) constitute the major threat to the welfare and safety of passengers. Taken out of context, as Mr. Forney has, this can of course be misconstrued to mean that "... disk and blade fragments (are a) major threat to welfare and safety of passengers". The intent was simply to identify which fragments present the worst threat. Whether or not rotor burst fragments or the incidence of rotor burst is a major threat in commercial aviation is a judgment that is clearly beyond the stated purpose or scope of the report being discussed.

A.K. Forney, FAA

The problem, Guy, of course, is that that report got some distribution and there was reaction, and we had to respond, you see. I don't know how much you got but I know we did, and it's difficult to respond to. Your statement claims to be based on FAA data, and so it is kind of difficult for us to answer the criticisms that we got. Clearly if your intent is what you have just stated, you can't tell it by reading that report; that's my point.

G.J. Mangano, NAPTC

All right, we'll take these recommendations under advisement and perhaps be more explicit in our future statements. Again, the intent of the report was to identify the extent of the problem, that's all. The conclusions made are so generally stated that they are subject to different interpretations by different people. I just wanted to explain what was meant by a major threat. By considering all of the fragments that were generated, the disk and the fan blades were the major threats, not that rotor burst per se is a major threat. I think we'll leave it up to the FAA to make that judgment. All that we do is to present the statistics of the situation. If I interpret Ken's words correctly, rotor burst is not a major threat. Again, I'll leave that judgment to the regulating agencies.

J.H. Enders, FAA

One might note that in these comments on the first paper we've exposed a very basic and common problem in research: human factors. Communication difficulties between human beings are increasingly recognized as a culprit in our business; one group trying to understand the other, whether it's the lay public vs. the technical community, or segments within the technical community itself.

Gordon Gunstone, CAA-UK

I just wanted to say that perhaps to save time on that particular point, if you'd comport yourselves with patience for ten minutes, I have some figures which I hope will illustrate exactly what the problem is or isn't.