U.S. Department of Transportation
Federal Aviation Administration

Policy Statement

Subject: Policy for Turbofan, Turbojet and Turboprop Engine Rotor Lock

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Initiated By: ANE-111

Policy No: PS-ANE-33.89-01

1 Summary

The FAA is providing policy on rotor lock screening during compliance demonstration to the starting requirements in part 33 of Title 14 Code of Federal Regulations during certification programs for turbofan, turbojet and turboprop engines. Rotor lock may have catastrophic consequences for an airplane. Applicants for engine type certificates should, therefore, determine the potential for rotor lock in turbofan, turbojet and turboprop engines and its impact on engine restart capability. Due to the influence of engine installation effects on rotor lock, applicants may use test or analysis to demonstrate compliance to part 33. Policy Statement PS-ANM-25-02 provides additional guidance for screening for rotor lock in part 25 installations of turbine engines.

2 Current Regulatory and Advisory Material

The following regulations from Title 14 of the Code of Federal Regulations (14 CFR) may apply:

Part 21: § 21.21(b)(2)

Part 33: §§ 33.5(b) 33.89(a)(1) and 33.89(b)

Part 25: §§ 25.903(e), 25.1351(d), and 25.1585(a)(3)

The Transport Airplane Directorate policy, PS-ANM-25-02, Guidance for Screening for Engine Rotor Lock in Transport Category Airplanes During Aircraft Certification, is also related.

3 Background

a. **<u>Defining Rotor Lock.</u>** Rotor lock is a transient temporary thermal condition where:

(1) An engine's core rotor speed decreases to zero following an in-flight shutdown or engine flame out, and

(2) The core rotor will not rotate during a subsequent windmill or assisted start attempt.

b. **Rotor Drag.** Another condition called “rotor drag,” caused by engine accessory loads or rotor/stator high-friction contact from loss of clearances, slows engine rotor speed during a windmilling situation. The screening criteria described in this policy is intended to address both rotor drag and rotor lock.

c. **Effects of Rotor Lock on Restarting.** Both rotor lock and rotor drag can prevent a successful restart of a windmilling engine. The presence of rotor lock or rotor drag characteristics, or both, that precludes a successful restart of an otherwise undamaged engine is considered unsafe. Additionally, compliance to § 33.89(b) requires an operations evaluation and demonstration that the engine has safe operating characteristics throughout the manufacturer’s specified operating envelope.

d. **Susceptible Features.** Modern aircraft engines incorporate technologies that may reduce the in-flight engine starting envelope and increase the time required to restart the engine. These technologies, which include changes in combustor designs, compressors, operating margins, accelerations schedules, use of bleed air, and supplementary power systems, need to be evaluated to assess the impact of rotor lock on restart capability. As core-bypass ratios of newer engines continue to increase, higher airspeeds are generally required to enable unassisted windmill restarting. The inertial effects because of the increased size, mass, and number of engine gearbox driven accessories may also contribute to increased rotor drag loads, decrease starting performance, and possibly contribute to rotor drag and rotor lock conditions. The engine’s high-pressure compressor rotor, or core rotor, is the only currently known rotating component of two- or three-rotor systems that slows and stops rotating during flight. Future engine designs may have different behavior.

e. **NTSB Recommendations.** In October 2004, an airplane accident occurred on a nonrevenue flight when the flight crew was unable to restart the engines after a high altitude flameout. While the National Transportation Safety Board (NTSB) concluded limited flight crew training and poor flight crew judgment during the flight were the probable causes of the accident, the NTSB also cited engine rotor lock as a contributing factor (ref. NTSB accident Report NTSB/AAR-07/01, dated January 9, 2007). The NTSB issued Safety Recommendations A-06-70 through A-06-76 (ref. November 29, 2006, letter to the FAA) as a result of this accident.

f. **FAA Actions.** This policy statement clarifies the need to assess engines for rotor lock. An all-engine power loss occurs infrequently but the consequences of not being able to restart engines from a windmilling condition can be catastrophic.

4 Policy

a. **Compliance.** Section 33.89 requires that the applicant must demonstrate acceptable starting capability. Since rotor lock is a condition that can prevent a successful start of a windmilling engine, rotor lock must be considered when demonstrating compliance to § 33.89.

b. **Key Elements to Consider.** A rotor lock assessment should maximize the thermal mismatch between the rotating hardware and static hardware during spool down and thermal cool down. Rotor lock screening assessments should consider the following key elements:

(1) Initial Thermal Conditions. A hot engine shut down (fuel cut-off) following sustained operation at high engine thrust. The engine should reach thermal equilibrium at the high engine thrust condition prior to shut down. This thermal state provides a high engine internal temperature at the start of spool down where the stator and case cool faster than the rotor.

(2) Flight Effects. The altitude when the engine is shutdown and during the engine spool down. High altitude results in low-density air entering the engine, which should allow for a large thermal gradient between the engine case and engine core rotor as well as reduce the airflow through the engine core. This provides an opportunity for the engine case to cool more quickly than the engine core rotor, which occurs during rotor lock events.

(3) Thermal Mismatch. A low airspeed that is a conservative representation of operational conditions, with a safety margin. This airspeed after shutdown is representative of a reasonably expected pilot's response, not the optimal response, where best glide speed is likely set while the flight crew troubleshoots the emergency for several minutes prior to descending in altitude to restart the engines. This kind of operation provides a low airflow through the engine core allowing the engine core rotor to quickly reduce speed and increase the opportunity for the engine case to cool more quickly than the engine core rotor.

(4) Dwell Time. A time duration at the low airspeed determined by 4.b.(3) of this policy statement, where the engine cools significantly and the rotor achieves the minimum windmill rotational speed; potentially coming to a full stop. Prior to initiating a restart, allow additional time for the rotor and stator interference to potentially occur.

c. **Detailed Assessment.** Since rotor lock falls within the requirements of § 33.89, a rotor lock assessment for new engine certifications, or major engine design change programs which directly affect the engine or installation characteristics that may influence rotor lock or rotor drag, should include a specific test or analysis assessment to address this condition.

d. **Reporting Results.** When rotor lock, rotor drag, hung start, or any condition adversely affecting restart capability is encountered during the assessment, mitigation is required in order to show compliance to § 33.89. Accordingly, engine type certificate applicants must provide actions to mitigate the issue. The FAA engine certification office should report the rotor lock issue and the mitigation plan to the Engine & Propeller Directorate's Standards Staff. The factors leading to the adverse condition and the effects on restart capability will indicate what actions may be appropriate.

e. **Supporting Information**. When rotor lock is found, additional analysis may be required to address:

(1) The severity and duration of the rotor lock-up, rotor drag, hung start, etc.,

(2) The airspeed at which zero core rotation speed is achieved,

(3) The delay and reliability of achieving restarts, and

(4) Any unexpected engine damage identified through borescope inspections

f. **Mitigations**. Potential actions to mitigate adverse conditions that result in rotor lock include, but are not limited to:

(1) Incorporate engine and/or installation design changes,

(2) Developing an in-flight or uninstalled engine seal grind-in procedure,

(3) Procedures to reduce drag from accessories,

(4) Use of starter-assist, if available in an all-engines-out condition (e.g., electrical starter with sufficient battery capacity), and

(5) Mandatory minimum airspeed operational limitations and procedures, possibly in combination with other mitigating actions, such as flight crew indications that will ensure limitations are not exceeded.

Newly-built and overhauled engines that are delivered to airlines as spare engines should be considered when developing mitigating actions. An in-flight engine seal grind-in procedure may not be able to address these engines.

A subsequent rotor lock assessment may be needed to demonstrate that mitigating actions have been successful.

5 Effect of Policy

The general policy stated in this document does not constitute a new regulation. Agency employees and their designees and delegations must not depart from this policy statement without appropriate justification and concurrence from the FAA management that issued this policy statement. The authority to deviate from this policy statement is delegated to Engine and Propeller Directorate Standards Staff Manager.

Similarly, if the project aircraft certification office becomes aware of reasons that an applicant's proposal that meets this policy should not be approved, the office must coordinate its response with the policy issuing office. Applicants should expect that certificating officials would consider this information when making findings of compliance relevant to new certificate actions. In addition, as with all guidance material, this policy statement identifies one means, but not the only means, of compliance.

6 Implementation

This policy should be applied to type certificate, amended type certificate, supplemental type certificate, and amended supplemental type certification programs with an application date that is on or after the effective date of the final policy. If the date of application precedes the effective date of the final policy the applicant may choose to either follow the previously acceptable methods of compliance or follow the guidance contained in this policy.

7 Conclusion

We have concluded that it is necessary to raise your awareness of the effects of engine rotor lock and rotor drag on the capability to restart an engine from an all-engines-windmilling condition after a rapid engine shutdown. We base this conclusion on the number of all-engines power loss events, the difficulty that flight crews experienced with in-flight starting of engines, and the new knowledge of engine rotor lock and rotor drag. If other data is presented that demonstrates otherwise, the intent and content of this policy will be reconsidered.

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