U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: STRUCTURAL SUBSTANTIATION OF PART 23 AIRPLANE MODIFICATIONS INVOLVING INCREASED ENGINE POWER

Date: 1/27/93
Initiated by: ACE-100

AC No: 23-12
Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance concerning acceptable means, but not the only means, of demonstrating compliance with the requirements of part 23 of the Federal Aviation Regulations (FAR) applicable to the structural substantiation of modifications involving increased engine power. This material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. RELATED REGULATIONS AND DOCUMENTS.

a. Subpart C of part 23 of the FAR.

b. "Substantiation for an Increase in Maximum Weight, Maximum Landing Weight, or Maximum Zero Fuel Weight," AC 23-7, Federal Aviation Administration (FAA), dated July 1, 1987.

3. BACKGROUND. The FAA has become aware of the need for guidance material concerning structural substantiation of part 23 airplanes for increased engine power. The guidance provided by this AC is intended to promote uniformity of application of the certification rules. In the past, some FAA approvals involving increased engine power have required complete structural substantiation regardless of the magnitude of the engine power or weight increase. Other approvals have been made on the basis of appendix A of the Civil Aeronautics Manual (CAM) 8, which permits engine changes with no additional structural substantiation, provided the engine weight increase is not greater than 10 percent of the originally certificated engine weight and the torque increase does not exceed 20 percent of the original torque corresponding to the originally certificated engine power.

4. DISCUSSION.

a. CAM 8 is applicable only to those restricted category airplanes that have part 8 of the Civil Air Regulations (CAR) as a certification basis. Its provisions should not be applied to supplemental type certification of modifications to small airplanes under parts 21 and 23 of the FAR, under parts 04, 4a, 03, or 3 of the CAR, or under Aeronautical Bulletin No. 7A.

b. For airplanes whose certification basis is part 03 or part 3 of the CAR, the guidance provided in paragraph 3.19-1 of CAM 3 is applicable to the subject modifications. For airplanes whose certification basis is part 04 or part 4a of the CAR, or Aeronautical Bulletin No. 7A, the guidance provided in the manual material under § 04.061 in CAM 04 is applicable to the subject modifications. Under this guidance, minor changes in engine weight are allowed with a minimum of structural testing or analysis if neither the existing approved maximum airplane gross weight nor any existing approved airspeed limitation is increased.

c. Many engine change modifications involve a power increase with no change in maximum weight or airspeed limitations and also do not involve a change from reciprocating to turbine engines. These modifications are the simplest type since they do not cause an increase in any flight or ground loads other than those acting on the engine mount, forward fuselage or engine nacelle and adjacent wing structure, and (due to increased slipstream) wing flaps, slats, and spoilers and their local supporting structure. A showing of structural compliance for such a modification will normally involve only a demonstration that the modified airplane complies with §§ 23.361, 23.363, 23.457(b), 23.459, and 23.701 as applicable.

d. A modification involving an increase in the weight and/or overhang moment of the engine and propeller installation as well as an increase in engine power will require a check of the structural strength of the forward fuselage or wing back to the point where it can be shown that the original structure is adequate to carry the additional loads due to the additional engine weight, torque, and overhang moment. If the engine is mounted on a flight surface and the installed weight is significantly increased, flutter in accordance with § 23.629 of the FAR may need investigating.

e. Increased engine power is considered an acoustical change. Consequently, § 21.93(b) is applicable to modifications covered by this AC.

f. This AC is applicable to piston engine conversions only. For conversion to turbine power, see AC 23-XX-17 (in draft).

5. METHOD OF SUBSTANTIATION.

a. Structural Substantiation by Analysis. Section 23.307 allows compliance with strength and deformation requirements by structural analysis if the structure conforms to those for which experience has shown the methods employed to be reliable. The procedures for structural analysis would generally be as follows:

(1) Determine the total weight and center of gravity (c.g.) of the engine installation including accessories and propeller.

(2) <u>Determine the effect</u> of the proposed engine installation on the airplane's weight-c.g. envelope as defined on the Type Certificate Data Sheet (TCDS) or Aircraft Specification, or by any Supplemental Type Certificates (STC's) that may have modified it. To minimize certification work, it is advisable to keep this envelope within the existing approved limits. If the weight-c.g. envelope is expanded beyond its existing approved limits in order to accomplish the proposed engine installation, all sections of part 23 of the FAR applicable to performance, flight characteristics, and structural loads should be reviewed for possible effects. Compliance with sections 23.21 through 23.31, which address load distribution and weight limits, must be shown.

(3) <u>Determine the limit flight load factors</u> required for maneuvering, gust encounters, and side loads (§§ 23.337, 23.341, and 23.363) for the category (normal, utility, or acrobatic) in which the airplane is certificated. Also, determine the limit landing load factors and angular accelerations required by §§ 23.471 through 23.479 (and § 23.521, if seaplane certification is desired), and from these determine the limit load factors acting at the engine installation c.g. under the landing conditions. Note that gust loads acting on engine mounts and their supporting structure at the design minimum weight are generally greater than those experienced at the design maximum weight.

Certain engine installations, particularly those mounted on wings, may experience high flight limit load factors due to the effect of angular accelerations added to linear accelerations under unsymmetrical flight conditions. In cases where the engine installation c.g. is unusually far from the airplane c.g., and in cases where the engines are mounted on the wings, limit flight load factors acting at the engine installation c.g. should be determined for the unsymmetrical flight conditions (§§ 23.347 through 23.351) and for conditions involving angular accelerations due to unbalanced components of tail load (§§ 23.423 through 23.443).

Large wing torsional loads may be experienced by airplanes having wing-mounted engines when high-lift devices are deployed. The limit flight load factors required by § 23.345 should, therefore, be determined for airplanes with engines mounted on the wings.

(4) <u>Determine the limit engine torque</u> corresponding to takeoff power and propeller speed. Torque may be determined from:

$$\text{Mean Torque (inch-pounds)} = \frac{63{,}025 \times \text{horsepower}}{\text{propeller speed (RPM)}}$$

For loads calculations, limit torque in accordance with § 23.361(c) at takeoff rating is considered to act in combination with 75 percent of the limit loads from flight condition A of § 23.333(d) and limit torque in accordance with § 23.361(c) at maximum continuous rating in combination with limit loads from flight condition A of § 23.333(d) [reference § 23.361(a)(1) & (2)].

NOTE: Section 23.361 contains an error as published by amendment 23-26. The correct requirements are implemented by policy, duplicated above. For reciprocating engines, the correct requirement is as published prior to amendment 23-26.

(5) Determine the limit engine torque corresponding to maximum continuous power and propeller speed, by multiplying the mean torque corresponding to maximum continuous power and propeller speed [as determined from the same equation used in (4) above] by the appropriate factor required by § 23.361(c). For loads calculations, this torque is considered to act in combination with the limit loads from flight condition A of § 23.333(d)[reference § 23.361(a)(2)].

(6) If the airplane has wing trailing-edge flaps, determine the airloads acting on them and the distribution of those loads with the engine(s) delivering takeoff power as required by § 23.457(b). Also determine the airloads acting on any other special aerodynamic devices, such as slats and spoilers exposed to the propeller slipstream (reference § 23.459). If airloads have increased, check the structural adequacy of the supporting structures and actuating systems of the flaps, slats, or other aerodynamic devices.

(7) Determine the engine mount reaction loads at the fuselage or engine nacelle attachment points for the conditions in paragraphs (3), (4), and (5) above, as applicable. For the most severe loading conditions, determine that:

(i) the engine mount and its attachment bolts are structurally adequate; and

(ii) for tractor-type airplane engines, the forward fuselage or engine nacelle and wing is structurally adequate. The adequacy of the structure should be verified back through the fuselage or wing structure containing the furthest aft of the following attachment points: main wing spar, main wing lift strut (if present), and forwardmost attachment point of the main landing gear; or back as far as that longitudinal station where it can be shown that the structure further aft is adequate to support the loads produced by these conditions. For pusher-type engine installations, the same procedure applies working forward to the above attachment points. The forward fuselage or engine nacelle may be unsymmetrical due to a single door opening on one side, or door openings being staggered. In this case, the side load required by § 23.363 may be more critical when applied toward one side than when applied toward the other.

b. Structural Substantiation by Comparison of Loads. To use this method, proceed according to paragraphs 5a(1) through 5a(7) above for the original engine installation. Then repeat the procedure for the proposed engine installation. Show that each critical load produced by the proposed engine installation is equal to or less than the corresponding load produced by the original engine installation. Note that this method cannot provide complete substantiation when the proposed engine installation requires that the airplane's weight-c.g. envelope be expanded or when any airspeed limit must be increased.

c. Structural Substantiation by Load Test. Determine the critical limit and ultimate loads from the procedure given in paragraphs 5a(1) through 5a(6) above. Except where specified otherwise by the applicable section of part 23 of the FAR itself, each ultimate load will be 1.5 times the corresponding limit load (reference § 23.303). Each structural element or assembly tested must be able to support limit loads without detrimental permanent deformation, and must be able to support ultimate loads for three seconds without failure (§ 23.305). For guidance in determining whether a structural failure has occurred in questionable or marginal test cases, see AC 23-6, "Interpretation of Failure for Static Structural Test Programs." Dynamic tests are acceptable if it is proven that they accurately simulate the design load conditions (reference § 23.307). A structure that has been tested to ultimate load cannot be used further as a flight article unless it is shown that the structure sustained no detrimental permanent deformation as a result of being subjected to the ultimate load. If a structure has been tested beyond limit load and has any detrimental permanent deformation, it should be clearly and permanently identified to prevent its use as a flight article. Be aware that composite structure can sustain serious damage without permanent set, requiring different inspection and acceptance criteria.

d. The effects on flutter and dynamic landing loads (§ 23.479(d)) due to an increase in propeller/engine weight, and/or shift in c.g., and changes in engine mount stiffness should be determined, particularly for wing-mounted engines. These items may require a ground vibration test and an analysis to ascertain the effect on the vibration and flutter characteristics of the airplane. Flutter considerations are thoroughly discussed in AC 23.629-1A, "Means of Compliance with Section 23.629, Flutter."

e. Flaps, Special Aerodynamic Devices, and Tail Surfaces. The need for substantiating the structure of wing trailing-edge flaps and special aerodynamic devices, and their operating mechanisms and supporting structure, under propeller slipstream loads has been discussed in paragraph 5a(6) above. As the slipstream is turbulent and rotates about the propeller axis, it also subjects flaps, special aerodynamic devices in the stream, and the tail surfaces (in the case of a tractor-type airplane) to dynamic, vibratory loads and, in the case of the horizontal tail surfaces, to unsymmetrical loads. Possible reductions in the fatigue life of flaps, special aerodynamic devices, and horizontal and vertical tail surfaces, and of their attachments, due to increased engine power should be addressed if the airplane's certification basis requires such a determination.

Unsymmetrical static loads on the horizontal tail surfaces need not be addressed when certificating an engine installation for an airplane originally certificated under part 23 of the FAR, or under parts 03 or 3 of the CAR, as these regulations contain sections that require the horizontal tail surfaces to be designed for unsymmetrical loading sufficiently great to account for increases in engine power (reference § 23.427 of the FAR and §§ 03.2214 and 3.218 of the CAR). Small airplanes certificated under parts 04 and 4a of the CAR, or under Aeronautical Bulletin 7A, however, were not required to demonstrate compliance with an unsymmetrical horizontal tail load condition. It may be necessary to require compliance with § 23.427, or with an equivalent special condition, when certificating increases in engine power for such airplanes [reference § 21.101(b) of the FAR].

f. <u>It is essential that the structural test article</u> conforms to the original or modified type design (§ 21.33). Prior to testing, the applicant should submit FAA Form 8130-9, "Statement of Conformity;" and the FAA will conduct a conformity inspection. A test proposal should also be submitted to the FAA for review and approval prior to testing. All structural tests should be witnessed by the FAA. The structure may be modified as a result of the tests. The final design submitted for FAA engineering approval should reflect any changes that have been made.

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