NASA Contractor Report 178321

Flight Service Evaluation of Advanced Composite Ailerons on the L-1011 Transport Aircraft

Fifth Annual Flight Service Report

R.H. Stone

LOCKHEED-CALIFORNIA COMPANY
BURBANK, CALIFORNIA

CONTRACT NAS 1-15069
June 1987

National Aeronautics and
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FOREWORD

This report was prepared by Lockheed-California Company, Burbank, California under Contract NAS 1-15069. It is the fifth and final annual report covering flight service evaluation of composite inboard ailerons on the L-1011 from July 1986 when the fourth yearly inspections were completed, through May 1987. The program is sponsored by the National Aeronautics and Space Administration (NASA), Langley Research Center. Mr. Marvin B. Dow is the Project Engineer for NASA.

C. F. Griffin is the Lockheed Engineering Program Manager and is being assisted in the flight service evaluation by R. H. Stone.

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SUMMARY

Four shipsets of graphite/epoxy composite inboard ailerons were installed on L-1011 aircraft in March through May 1982 for a five-year maintenance evaluation program. These include two Delta aircraft and two TWA aircraft. A fifth shipset of composite ailerons was installed in 1980 on Lockheed's flight test L-1011.

Results of the fifth and final annual inspection of the four shipsets of airline components are reported herein. The previous four inspections had been visual inspections of the aileron exterior surfaces. For this final inspection, the lower cover was removed for access. Both interior and exterior surfaces as well as spars, ribs and fastener holes were inspected.

No damage or defects were observed on any of the composite ailerons. No maintenance actions had occurred on any of the parts except for repainting of areas with paint loss. Flight hours on the airline components at the time of inspection ranged from 14,597 to 17,180 hours, after approximately five years of service.

SECTION 1
INTRODUCTION

In 1977 the Lockheed-California Company initiated a program to demonstrate the weight and cost-saving potential of secondary aircraft structures constructed of advanced composite materials. The component selected for this demonstration was the inboard aileron of the L-1011 transport aircraft. The program is sponsored by the National Aeronautics and Space Administration as part of the Aircraft Energy Efficiency (ACEE) Composite Structures Program.

The program scope included the evaluation of alternate designs and materials for the aileron; detail design and analysis; fabrication and test of subcomponents for design verification; fabrication and testing of two ground test ailerons; fabrication of five shipsets of ailerons for installation on L-1011 aircraft; flight testing of one shipset on Lockheed's flight test aircraft; and the 5 year flight service evaluation discussed herein. The overall program is summarized in the executive summary report (Reference 1). Lockheed's team member on this program was Avco Aerostructures Division of Avco Corporation. Avco was responsible for fabrication of the composite ailerons.

The composite aileron design, shown in Figure 1, is a multirib configuration with single piece upper and lower covers mechanically fastened to the substructure. Three basic materials were utilized in the aileron design: Narmco 5208/T300 graphite/epoxy unidirectional tape; Narmco 5208/T300 graphite/epoxy bidirectional fabric; and Hysol ADX 819 syntactic epoxy core.

The aileron covers, ribs, and front spar were fabricated using standard vacuum bag autoclave molding procedures. The aileron covers are thin sandwich plates with graphite/epoxy tape facesheets and a syntactic epoxy core. The

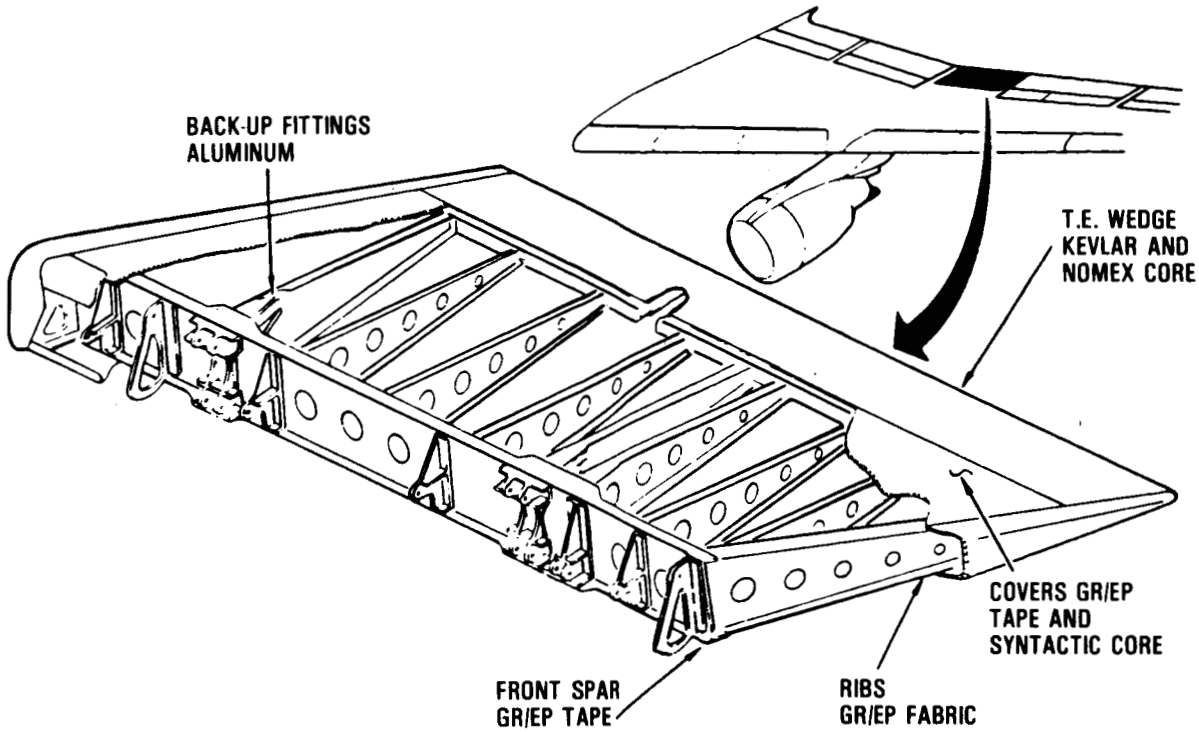

Figure 1. - Advanced Composite Aileron Assembly

ribs and spars are constant thickness channel sections, laid up and cured on male tools. The intermediate ribs are fabricated of bidirectional graphite/epoxy fabric. The main ribs which react hinge and actuator loads are fabricated of graphite/epoxy fabric, with the caps reinforced with graphite/epoxy tape. The front spar is fabricated of graphite/epoxy tape laid up in approximately a quasi-isotropic orientation.

The complete aileron assembly includes an aluminum leading edge shroud, aluminum bathtub fittings at the spar to main rib joints, fiberglass/epoxy fairings, aluminum hinge/actuator fittings, and a Kevlar 49/epoxy trailing edge. The composite aileron design is 26% lighter than the metal aileron and is predicted to be cost competitive since the composite aileron has 50% fewer parts and fasteners than the metal aileron.

The inboard aileron is located on the wing trailing edge between the outboard and inboard trailing edge flaps. It is supported from the wing at two hinge points and is actuated by three hydraulic actuators. It is a wedge-shaped, one-cell box, thinning slightly from root to tip. At the front spar the aileron is 233.7 cm (92 in.) in length and approximately 25.4 cm (10 in.) deep. The width of the aileron is 127 cm (50 in.). The upper surface, ribs, and spars are permanently fastened using titanium Triwing screws and stainless steel Hi-Lok collars. The removable lower surface, trailing edge wedge, and end fairings are attached with the same type screws but with nut plates attached to the structure with A286 Cherry Rivets. All fasteners are installed with sealant. The aileron is primed and painted with standard aircraft materials.

SECTION 2
FLIGHT SERVICE EVALUATION PLAN

The final phase of the inboard aileron program is a five-year flight service evaluation. A left-hand and right-hand aileron were installed on four new L-1011 aircraft. Two of these aircraft were subsequently delivered to Delta Air Lines, and the two others were delivered to Trans World Airlines. The Delta aircraft were the standard L-1011-1 model, while the TWA aircraft were longer range L-1011-100s.

The evaluation agreement between Lockheed and the two participating airlines consisted of the following elements:

1) The evaluation period is five years.

2) An exterior visual inspection will be performed by airline personnel and witnessed by Lockheed personnel at annual scheduled "C"-check inspections closest to the anniversary of installation.

3) An interior inspection, requiring removal of the lower cover, will be conducted at the end of the five-year evaluation by airline personnel, witnessed by Lockheed personnel.

4) The airlines will provide a written report to Lockheed on the results of each inspection. This report will include inspection results, a description of any maintenance or repair actions, flight hours, number of landings, and utilization rate for the year.

5) In the event visible damage is observed, the airlines will determine the extent of damage by ultrasonic inspection using standards provided by Lockheed. After notification of Lockheed, the airline will repair the damage in accordance with the L-1011 Structural Repair Manual, which was revised to incorporate specific repair procedures for the composite ailerons.

A fifth shipset of ailerons was installed on the Lockheed flight test airplane as part of FAA certification. These flight tests are described in the Task IV Final Report (Reference 2). A visual inspection of the exterior and interior aileron surfaces was conducted by Lockheed personnel after the

first and second years of flight service. The third-year inspection was cancelled since there had been only 10-1/2 hours flight-time during the previous year. The ailerons were given an exterior visual inspection after four years of flight service, which was just prior to sale of the aircraft to Aviation Sales Co. of Miami, Florida. Aviation Sales, who is using the aircraft for spares, thus acquired the composite ailerons.

SECTION 3
AILERON FLIGHT SERVICE EXPERIENCE

The first, second, third and fourth annual flight service inspections of the five aileron shipsets were conducted in March through July of 1983, April through July of 1984, April and May of 1985, and February through April of 1986. The results of these inspections are given in the First, Second, Third and Fourth Annual Flight Service Reports (References 3, 4, 5 and 6). Only one incidence of minor damage has been observed in any of these inspections (Reference 6).

The fifth annual inspections reported herein complete the aileron flight service evaluation. Previous airline inspections had been exterior visual inspections only (see Section 2), but for the final year visual inspections were performed on both interior and exterior surfaces as well as spars, ribs and fastener holes, after removal of the lower cover.

These fifth annual inspection results are summarized in Table 1, along with utilization rate and aircraft flight-hours and landings as of the inspection date for the composite ailerons. A total of 128,570 component flight-hours were accumulated through April 1987 on the ten installed ailerons. The high time ailerons have accumulated 17,180 flight hours in five years.

No damage, defects or evidence of maintenance actions were observed on any of the eight ailerons. Minor paint loss was observed in most cases, and fairly extensive paint loss (15-20%) was noted on the lower surface of one TWA component. There was also evidence of Skydrol exposure in most cases, particularly along the main rib attachment locations directly aft of the actuators. Skydrol exposure was also noted on the forward surface area of the main ribs.

TABLE 1. CUMMULATIVE FLIGHT SERVICE SUMMARY - FIFTH YEAR

Operator	Aircraft Tail No. (Lockheed Serial No.)	Date of Delivery	Date of Inspection	Cum. Flt-Hrs at Inspection		Cum. Landings at Inspection		Util. Rate (Hrs/Day)	Inspection Results Fourth Annual Inspection	Inspection Results Fifth Annual Inspection
				4th Annual Insp	5th Annual Inspec	4th Annual Insp	5th Annual Inspc	Five Yrs Flt Svc Period		
Delta	N736DY (1227)	Mar 11, 1982	Feb 16, 1987	12,531	14,939	6820	8079	8.3	No defects or damage to graphite components. Surface damage on fiber-glass end fairing noted and repaired. Parts repainted Nov 1985.	No discrepancies observed on either part.
Delta	N737D (1228)	May 8, 1982	Feb 15, 1987	12,051	14,597	6431	8073	8.4	No discrepancies observed on either part.	No discrepancies observed on either part.
TWA	N8034T (1230)	Apr 7, 1982	Apr 10, 1987	13,943	17,069	3618	4539	9.3	No defect or damage to graphite components. Paint chipping noted on all surfaces.	No defects or damage to graphite components. Paint chipping observed on upper and lower exterior skin surfaces.
TWA	N7035T (1231)	Apr 29, 1982	Apr 22, 1987	14,046	17,180	3626	4540	9.4	No defects or damage to the graphite components. Paint chipping noted on all surfaces, with 20% loss noted on lower surface of RH part.	No defects or damage to graphite components. Paint chipping observed on upper and lower exterior skin surfaces. (15-20% on RH lower surface) No evidence of fastener hole elongation or fraying noted. About 15% of Triwing screws had to be drilled out during lower cover removal, but this is typical for metal parts as well.
Lockheed	(1001)	June 3, 1980 (1)	---	462	(2) 500	(3)	(3) 390	0.22	Loose fibers noted around one fastener on forward edge, lower surface of LH part. Paint chipping noted on all surfaces, with 15% loss on upper surface of LH part.	No inspection, since aircraft has been sold.
	Totals			53,033	64,285	20,855	25,621			

(1) Date of composite aileron installation (2) Exact number of aileron flight-hours at end of final flight of Ship 1001 (3) Estimated number of landings based on typical ratio of landings to flight hours provided by L-1011 Flight Test.

Paint loss of this type is a fairly common occurrence on metal or fiberglass components. The significance for the graphite/epoxy ailerons is: 1) paint loss indicates that the ailerons are being exposed to hydraulic fluid, and the lack of damage verifies the resistance of graphite/epoxy to aircraft fluids; 2) the upper surface is exposed to ultraviolet, and epoxy resins are known to be affected by ultraviolet with significant weight losses after extended exposure. Airline maintenance personnel were advised of the need for repainting of exposed graphite/epoxy, particularly on the upper surface.

This inspection provided the only opportunity for a visual examination of the inner skin surfaces, the composite substructure (front spar, main ribs, intermediate ribs) and the condition of the fastener holes. In at least one case, TWA Ship N7035T, a careful and thorough visual inspection was made of all fastener holes. There was no observed damage or defect areas in any of the inner surfaces or substructure, and no fastener hole elongation or fraying was noted.

Aviation Sales Co. was contacted in May, 1987, regarding disposition of the two composite aileron components that were installed on the Lockheed flight test airplane purchased by Aviation Sales. These parts have been removed and are in storage in Miami, Florida. They are reported to be in good condition, and are available as spares.

In summary, results of the five-year flight service evaluation indicate that the graphite/epoxy components perform satisfactorily in the high utilization environment of commercial transports. The satisfactory structural performance of the ailerons and the absence of major damage or defects verifies the structural and durability data obtained in the composite aileron test program.

These inspections complete the flight service evaluation program. The graphite/epoxy ailerons will be retained by Delta and TWA, and at their option will remain in service as standard production components.

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15. Supplementary Notes

Langley Technical Monitor: Marvin B. Dow
Fifth Annual Flight Service Report

16. Abstract

This report covers flight service evaluation of composite inboard ailerons on the L-1011 under Contract NAS1-15069 for a period of five years. This is the fifth and final annual report of the maintenance evaluation program, and covers the period from July 1986 when the fourth yearly inspections were completed, through May 1987.

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