Design and Experimental Verification of the USB Flap Panel Structure for NAL-STOL Research Aircraft

Masaaki Sano*
National Aerospace Laboratory, Tokyo Japan
Yoshinori Fujimori†
National Space Development Agency of Japan Tokyo, Japan
and
Shoji Maekawa‡
Kawasaki Heavy Industries Ltd , Gitu Japan

Abstract

SINCE the USB flap of the NAL STOL research aircraft is one of the primary design modifications of the original C 1 transport aircraft an acoustic fatigue test of substructural models at an elevated temperature was conducted to verify the safety of the flap structure during the planned flight evaluation program Five structural models were provided and the following test items were carried out: 1) detection of the thermal buckling temperature 2) vibration tests and 3) acoustic fatigue tests at elevated and room temperatures

The conclusions reached in the experiments are summarized as follows: 1) thermal buckling occurred on test panels 2) resonant frequencies of the flap test panels fall in the range between those of clamped and simply supported plates and 3) throughout the prescribed fatigue test period all structural models have proven to be strong enough to resist both acoustic and thermal loading In addition to the laboratory verification analytical determination of response has been obtained and the fatigue life has been estimated based on the assumption that the flat test panels were uniformly loaded by heat and noise

Contents

National Aerospace Laboratory (NAL) is presently developing a research STOL aircraft which adopts upper surface blowing (USB) double flap configuration as a high lift device Since the upper surface of the main wing and USB flap are exposed to thermal and acoustic loadings from the high temperature exhaust gas of FJR 710 engines it is required to guarantee that the USB flap structure has enough acoustic fatigue life to withstand both acoustic and thermal loading during prescheduled flight test hours This paper presents the results of acoustic fatigue tests fatigue life estimation based on computer simulation or on real time strain history and dynamic response

USB Flap Structure

The USB flap structure consists of two parts: the fore and main flaps as illustrated in Fig 1 The upper surfaces of both fore and main flaps are fabricated from Ti 6Al 4V sheet panel with 1 8 mm thickness The lower surface is fabricated from 2 5 mm thick 2024C T3 panels The trailing edges of both flaps are tailored smoothly by wedge shaped polyimide honeycomb panels

Acoustic Fatigue Design

Numerical simulation was used to determine the panel thickness at the initial design phase The noise input or the exciting force of the panel can be approximated by the two straight lines shown in Fig 2 in terms of the spectrum produced by the FJR 710 engine [1] One example of the simulation result is illustrated in Fig 3 where thickness and temperature are varied as parameters which shows that a plate of 1 8 mm thickness seems adequate enough to withstand the maximum input noise more than 103 at 200 C

Since the noise level (OASPL) varies depending on the flight condition or the mode of maneuver the structural damages to the panel from various noise levels should all be adjusted so that their relative contributions are determined in terms of the equivalent duration at the maximum noise level Thus it is concluded that a 140 h endurance test with OASPL = 160 dB at 150 C would be sufficient to clear the safety requirement of the flap structure [2]

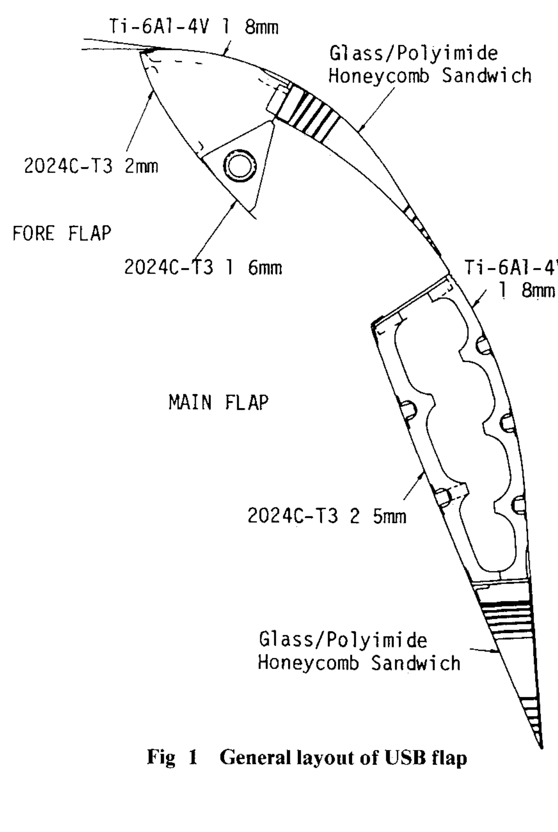

Fig 1 General layout of USB flap

Received Jan 24 1983; revision received July 6 1983 Full paper available from National Technical Information Service Springfield Va 22151 by title at the standard price

Senior Engineer 2nd Airframe Division
†Senior Engineer 1st Satellite Design Group
‡Senior Engineer STOL Design Division

Table 1 Acoustic fatigue test hour

	Specific test			Acceleration test						Total T	
Panel	OASPL dB	Temp C	t_s h/min	Frequency range	OASPL dB	Temp C	St G rms ratio	Acceleration factor	t_a h/min	t_e	$t_s + t_e$
A	160 / 163 5	150	71:26	300 500	156 4	150	100/70	5 3 / 4 66	42:05	223 / 195	294 / 266[a]
B	160 / 159 9	Room temp	71:26	300 500	155 2	Room temp	100/40	72 / 84 5	42:05	3030 / 3551	3100 / 3621
C	160 / 156 2	150 170	31:37	600 800	156 / 155 7	150 170	51/41	2 8 / 1 134	12:30	35 / 14:10	66:37 / 45:47
D	160 / 158 1	150	22:17	400 630	154 / 154 9	150	90/60	6 6 / 6 97		218 / 230	240 / 252
E	160 / 157 3	Room temp	22:17	400 630	154 / 153 7	Room temp	50/14	380 / 31 6	33:08	12600 / 1043	12600 / 1065

[a] Hour obtained by computer data processing

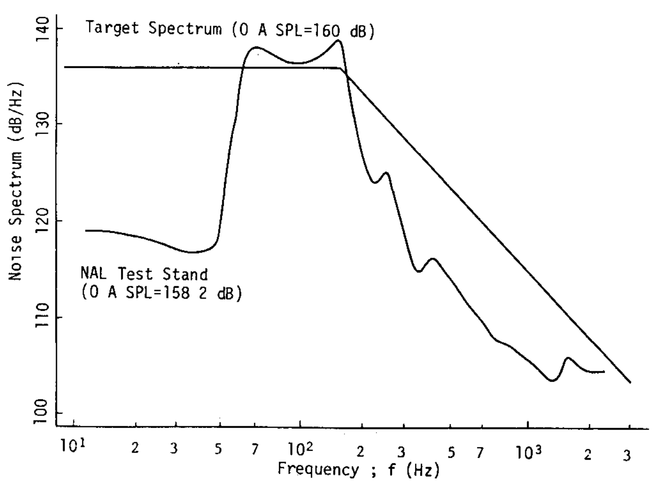

Fig 2 Noise spectrum

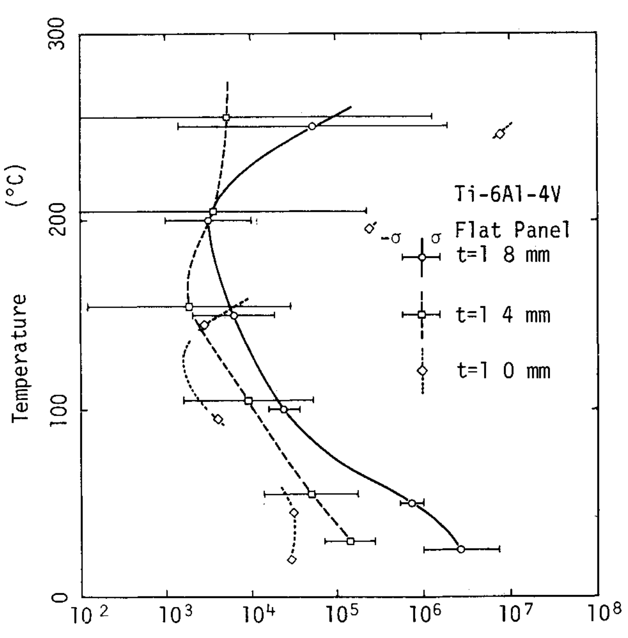

Fig 3 Fatigue life estimate by numerical simulation

Test Panel

Three test panel structure models which typify a so called 9 bay semimonocoque structure were considered; the first one represents the upper surface of the main flap (A) the second one the lower surface of the main flap (B) and the third one the surface of the fore flap (C)

Thermal and Dynamic Characteristics of the Test Panels

Resonant Frequency

Resonant frequencies of the flat panels occur in the range between those of clamped and simply supported plates However the resonant frequencies of curved panels (C) are close to those of the simply supported plate

Static Thermal Response

In order to detect the thermal buckling temperature of test panels the equilibrium thermal strain trend is pursued during the gradual heating on the face side up to 200 C

Dynamic Response

Since the strain level is low smaller than 50M strain and no oil canning type vibration occurs the significant damage to the structure cannot be expected at specified noise input and thermal conditions

Acoustic Fatigue Test

Table 1 summarizes the acoustic fatigue test conducted in the NAL Acoustic Test Stand In the acceleration test the noise input to various test panels is adjusted so that the rms strain response increases Thus the acceleration test hours depend on this rms strain response increases Thus the ac celeration test hours depend on this rms ratio No visible damages were detected on any of the test panels

Conclusion

In spite of insufficient technical data available on acoustic fatigue life estimation at elevated temperatures the designed flap structures have been successfully proved to possess adequate fatigue strength under the predicted noise and thermal loads Moreover the panels with reduced thickness have also proved to have sufficient fatigue strength

References

[1] Maita M and Torisaki T Acoustic Characteristics of the External Upper Surface Blowing Propulsive Lift Configuration AIAA Paper 80 1063

[2] Maekawa S , On the Sonic Fatigue Lift Estimation of Skin Structures at Room and Elevated Temperatures *Journal of Sound and Vibration* Vol 80 Jan 1982 pp 41 59