Compressive Strength of Titanium Alloy Skin-Stringer Panels Selectively Reinforced with Boron-Aluminum Composite

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Theme

RESULTS are reported from an effort to demonstrate the feasibility of selectively reinforcing a titanium airframe structure with thin strips of unidirectional B-Al composite attached by brazing. A number of riveted skin-stringer panels were fabricated with and without composite reinforcement on the hat-section stringer, and tested to failure in endwise compression. The objectives were to verify experimentally the increased structural efficiency attainable with the reinforced panels, and to demonstrate the structural integrity of the braze between composite and metal. Tests were conducted at temperatures up to 800°F, and the experimentally determined values of buckling strength and maximum strength were compared with the results predicted by existing analytical methods.

Content

The basic specimen was a 10-in. long skin-stringer panel with the cross section shown in Fig. 1. The single hat-section stringer was brake-formed from annealed 6Al-4V titanium alloy sheet and fastened to a skin of the same material with stainless steel rivets countersunk flush with the outer skin surface. A total of 23 panels were fabricated, nine of which were reinforced with unidirectional B-Al strips on both surfaces of the cap of the stringer. The composite strips were fabricated commercially by winding 0.004-in. diam silicon carbide coated boron filament onto a 0.001-in. thick foil of 718 aluminum brazing alloy, then plasma spraying 6061 aluminum alloy into the filament array. The resulting composite monolayer was stacked and consolidated by heating above the melting temperature of the brazing alloy. The volume fraction of filaments in the composite was 0.46. Brazing of the strips to the stringers was accomplished under contact pressure in vacuum at 1130°F using 0.003-in. thick 718 aluminum alloy foil as the filler.

Panel specimens were failed in endwise compression at temperatures up to 800°F with the edges supported as shown in Fig. 1. Data were obtained in the form of load-shortening curves. Typical curves are presented in Fig. 2 for reinforced panels tested at room temperature and at 800°F. The initial deviation from linearity represents the onset of local elastic buckling in the skin of a given panel. Failure occurs at the indicated maximum load by crippling of the stringer and effective skin. Results of the buckling strength determinations are summarized in Fig. 3 for all the panels tested. Experimental and calculated buckling strengths are compared for both reinforced and unreinforced panels over the entire test temperature range. The comparison is made in terms of the ratio of the uniformly distributed load per unit width, N, to the weight equivalent titanium thickness, t_e, where

$$t_e = (1/W)(A_{Ti} + (A\rho)_c/\rho_{Ti})$$

W is the width of a panel specimen, A_{Ti} is the titanium cross section, A_c is the composite cross section, and ρ is density. The calculated buckling strengths were obtained using the computerized analysis of Ref. 1, which makes use of minimum energy principles to obtain the critical buckling loads of stiffened panels composed of orthotropic laminated elements. The agreement between experiment and theory is good except for room temperature tests of reinforced panels and 800°F tests of unreinforced panels. No explanation is offered for either of these discrepancies other than to note that some uncertainty is associated with the determination of experimental buckling loads from the load-shortening curves. Both the experimental and the calculated results exhibit a gradual decline with increasing temperature. The improvement in equivalent weight structural performance resulting from the addition of B-Al composite

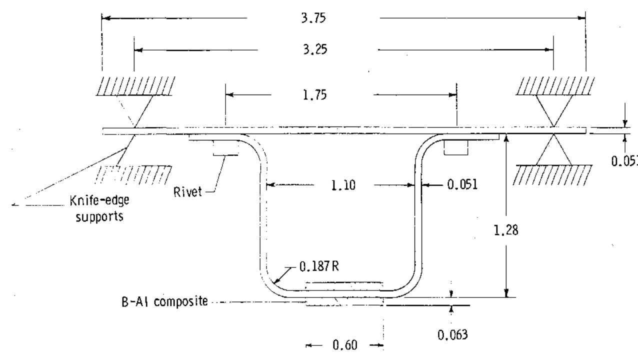

Fig. 1 Cross section of 6-4 titanium alloy skin-stringer panel reinforced with boron-aluminum composite.

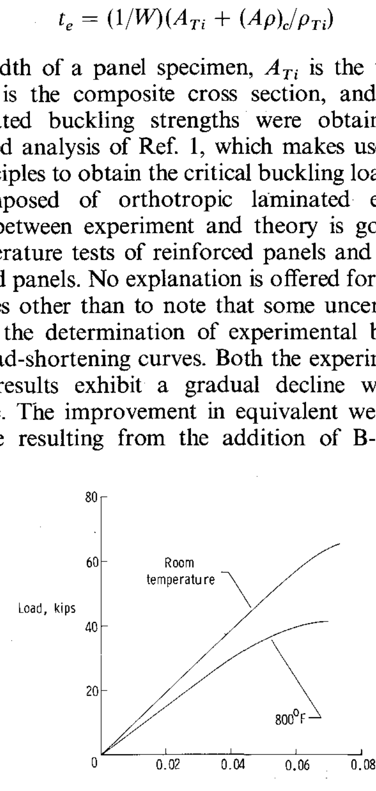

Fig. 2 Typical load-shortening curves from compression tests of titanium skin-stringer panels with composite reinforcement. Cross section area is 0.486 in.^{2}

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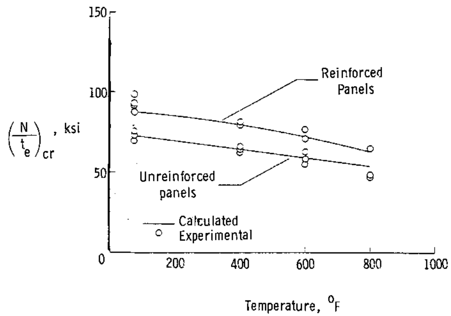

Fig. 3 Comparison of titanium weight equivalent buckling strengths of reinforced and unreinforced skin-stringer panels on the basis of temperature.

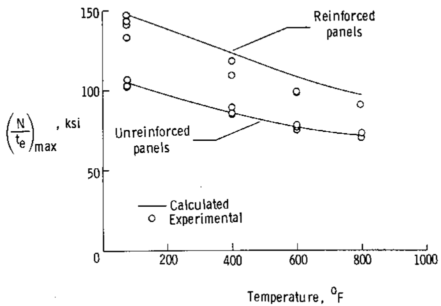

Fig. 4 Comparison of titanium weight equivalent maximum strengths of reinforced and unreinforced skin-stringer panels on the basis of temperature.

is approximately 25% up to 600°F. The improvement is 35% at 800°F based on the experimental results.

Experimental and calculated maximum strengths are compared in Fig. 4. The calculated results were obtained from conventional analytical methods used in aircraft structural design (see Refs. 2 and 3). Agreement is good for unreinforced panels, but the calculated strengths for reinforced panels are higher than the experimental results. The lack of agreement in the latter case is attributed to the fact that the stress-strain curve for the B-Al composite was not known. The stress-strain curve is known to be bilinear. However, the secondary elastic modulus for the material was unknown, necessitating the use of the initial elastic modulus in the calculation of maximum strength. The improvement gained by adding the composite strips ranges from about 35% at room temperature to 25% at 800°F, again on an equivalent weight basis.

The braze-bond between the B-Al composite and the titanium alloy stringers proved to be completely satisfactory. No evidence of bond failure was observed under any of the test conditions.

References

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