View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by NASA Technical Reports Server

N91-10303

REPEATED BUCKLING OF COMPOSITE SHEAR PANELS

Josef Singer* and Tanchum Weller**
Faculty of Aerospace Engineering
Technion - Israel Institute of Technology
Haifa 32000, Israel.

---

*L. Shirley Tark Professor of Aircraft Structures, Fellow AIAA
**Associate Professor, Member AIAA

PRECEDING PAGE BLANK NOT FILMED

REPEATED BUCKLING OF COMPOSITE SHEAR PANELS

SUMMARY

Failures in service of aerospace structures and research at the Technion Aircraft Structures Laboratory have revealed that repeatedly buckled stiffened shear panels might be susceptible to premature fatigue failures. Extensive experimental and analytical studies have been performed at Technion on repeated buckling, far in excess of initial buckling, for both metal and composite shear panels with focus on the influence of the surrounding structure (see for example Refs. 1 and 2).

The core of the experimental investigation consisted of repeated buckling and postbuckling tests on "Wagner beams" in a three-point loading system under realistic test conditions. The effects of varying sizes of stiffeners, of the magnitude of initial buckling loads, of the panel aspect ratio and of the cyclic shearing force, V_{cyc}, were studied. The cyclic to critical shear buckling ratios, (V_{cyc}/V_{cr}) were on the high side, as needed for efficient panel design, yet all within possible flight envelopes. The experiments were supplemented by analytical and numerical analyses.

For the metal shear panels the test and numerical results were synthesized in Ref. 2 into prediction formulas, which relate the life of the metal shear panels to two cyclic load parameters: the (working/buckling) load ratio, (V_{cyc}/V_{cr}), and the (ultimate/working) load ratio, (V_{ult}/V_{cyc}), which reflects the working load level in the flight envelope, and one geometrical parameter: the (plate/stiffener) stiffness ratio, (b^3t/I_f). It was also found there that the level of shear load, at which local yielding first takes place, V_y dominates the endurance of the panel, and hence the life predictions could be expressed in a simpler manner, in terms of a single load ratio (V_{cyc}/V_y).

The composite shear panels studied were hybrid beams with Graphite/Epoxy webs bonded to aluminum alloy frames (see Fig. 1). The test results (see Refs. 3 and 4)* demonstrated that composite panels were less fatigue sensitive than comparable metal ones, and that repeated buckling, even when causing extensive damage, did not reduce the residual strength by more than 20 percent. All the composite panels sustained the specified fatigue life of 250,000 cycles. The extent of damage depended on the working load level V_{cyc}, but no matter how pronounced it was it did not affect the fatigue life and did not result in immediate catastrophic failure (see Fig. 2 for damages in a typical test).

---

*See reference list.

The effect of local unstiffened holes on the durability of repeatedly buckled shear panels was studied for one series of the metal panels (see Ref. 5). Tests on 2024 T3 aluminum panels with relatively small unstiffened holes in the center of the panels demonstrated premature fatigue failure, compared to panels without holes. Even very small holes (of 3 mm diameter and less) caused very significant reductions in fatigue life, already at a relatively low load level, for which no fatigue failure is predicted in the case of similar unperforated panels. The holes caused a shift in the mode of the fatigue failure, initiating now instead of in the corners of the shear web in its center (see Fig. 3). Holes with initially introduced cracks were compared with smooth ones, the former exhibiting more pronounced life degradation, especially for the smaller holes.

Preliminary tests on two graphite epoxy shear panels with small holes in the center showed no similar fatigue life degradation and no shift in failure mode (see Fig. 4). Further tests on the effect of holes are in progress.

REFERENCES

1. Ari-Gur, J., Singer, J. and Libai, A., "Repeated Buckling Tests of Stiffened Thin Shear Panels", Israel Journal of Technology, Vol. 20, 1982, pp. 220-231.
2. Weller, T., Kollet, M., Libai, A. and Singer, J., "Durability Under Repeated Buckling of Stiffened Shear Panels", *ICAS 1984, Proceedings of the 14th Congress of the International Council of the Aeronautical Sciences*, Laschka, B. and Staufenbiel, R., Eds., International Council of the Aeronautical Sciences, Toulouse, France, Sept. 1984, pp. 932-942; Synoptic in J. of Aircraft, Vol. 24, No. 1, 1987, pp. 6-7.
3. Weller, T., Messer, G. and Libai, A., "Repeated Buckling of Graphite Epoxy Shear Panels With Bonded Metal Stiffeners", TAE Report No. 546, Department of Aeronautical Engineering, Technion - Israel Institute of Technology, Haifa, Israel, 1984.
*4. Weller, T. and Singer, J., "Durability of Stiffened Composite Panels Under Repeated Buckling", (to be published in International Journal of Solids and Structures - Babcock Memorial Issue).
5. Weller, T., "Effect of Local Unstiffened Holes on the Durability of Shear Panels Subjected to Repeated Buckling", *Fatigue Life Analysis and Prediction*, Goel, V.S., Ed., American Society of Metals, 1985.

---

*Not available at time of publication.

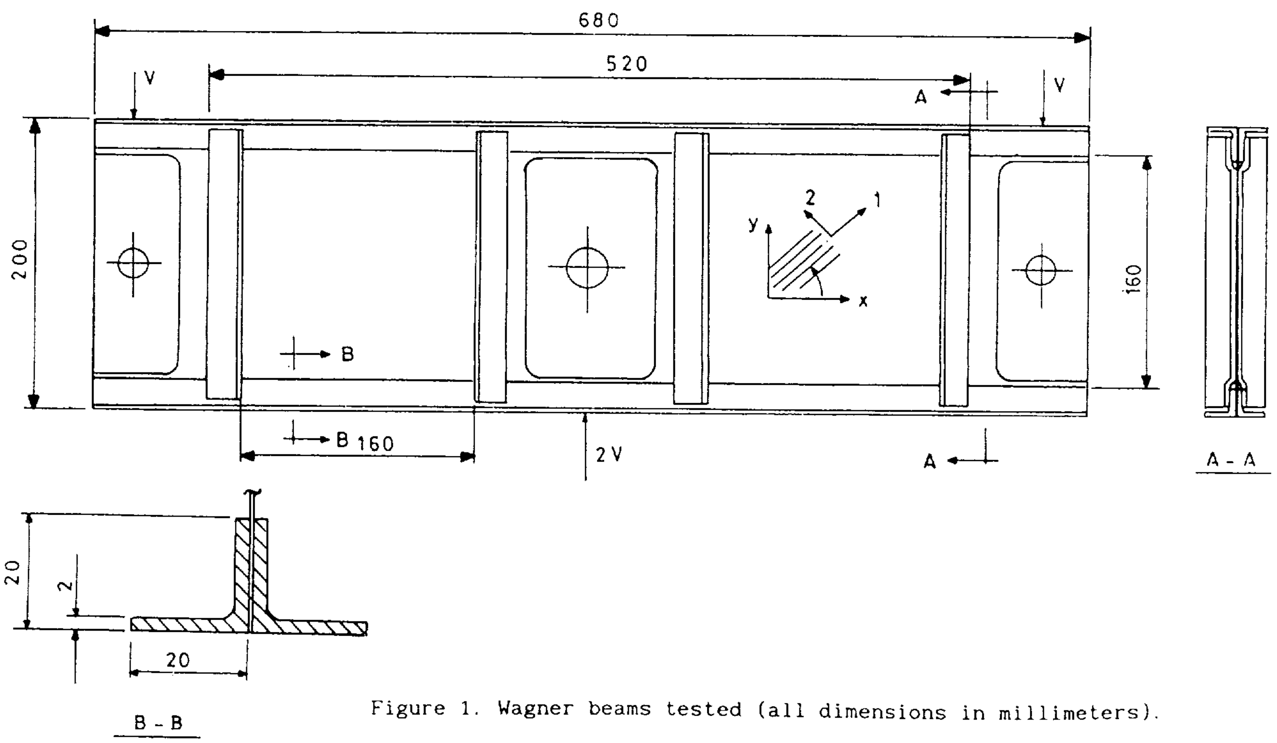
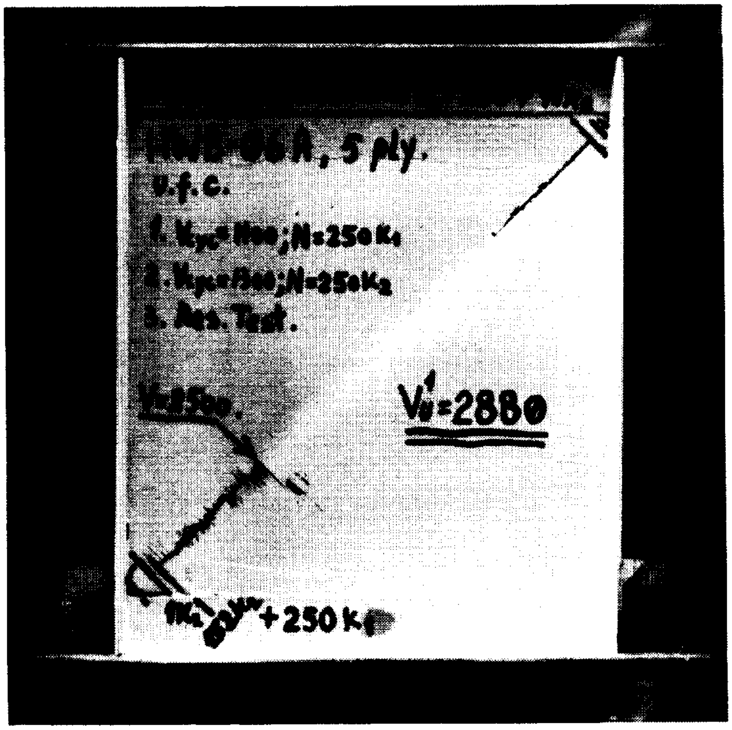
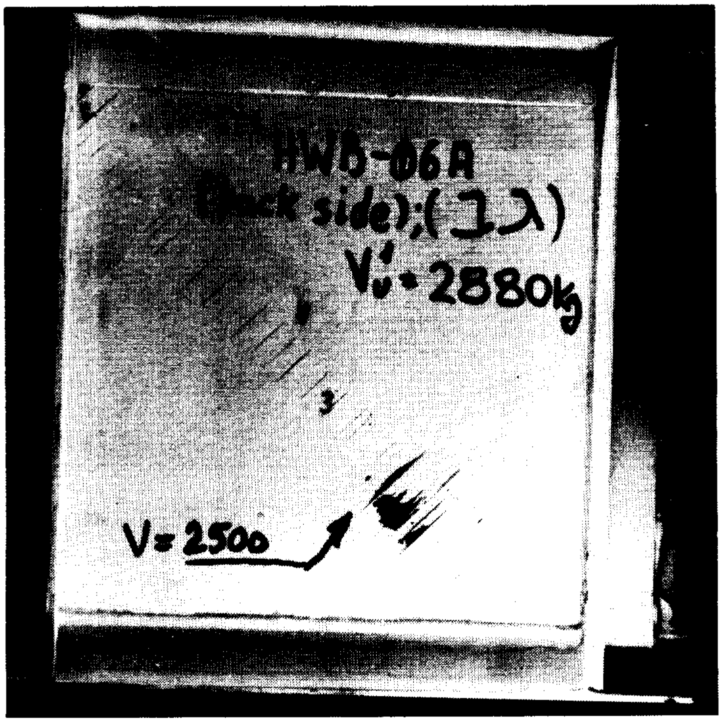


Figure 1. Wagner beams tested (all dimensions in millimeters).



ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 2. Typical failure mode of a graphite/epoxy panel (HWB 6A), dynamically loaded through two complete "fatigue lives" of 250,000 cycles each, and then tested statically from (Weller & Singer, 1990).

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

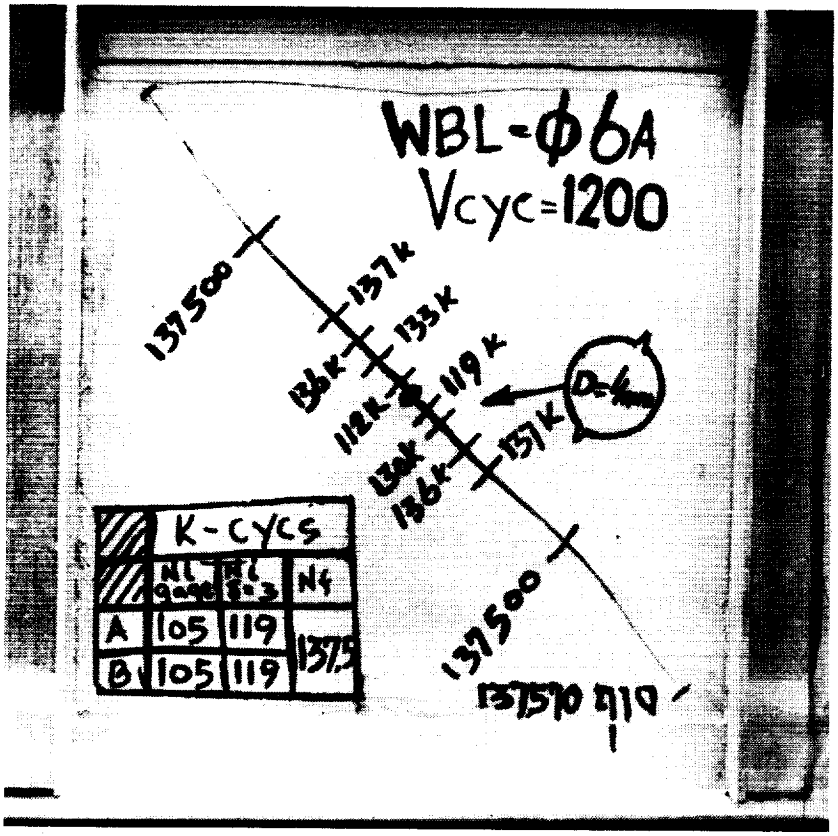


Figure 3. Fatigue failure of 2024 T3 aluminum alloy shear panel, with a central hole of 4 mm diameter (WBL 6A), after 137500 cycles at V_{cyc}=1200 kg. The failure occurs as a crack perpendicular to the tension diagonal initiating at the hole (two initial cracks made matters worse here).

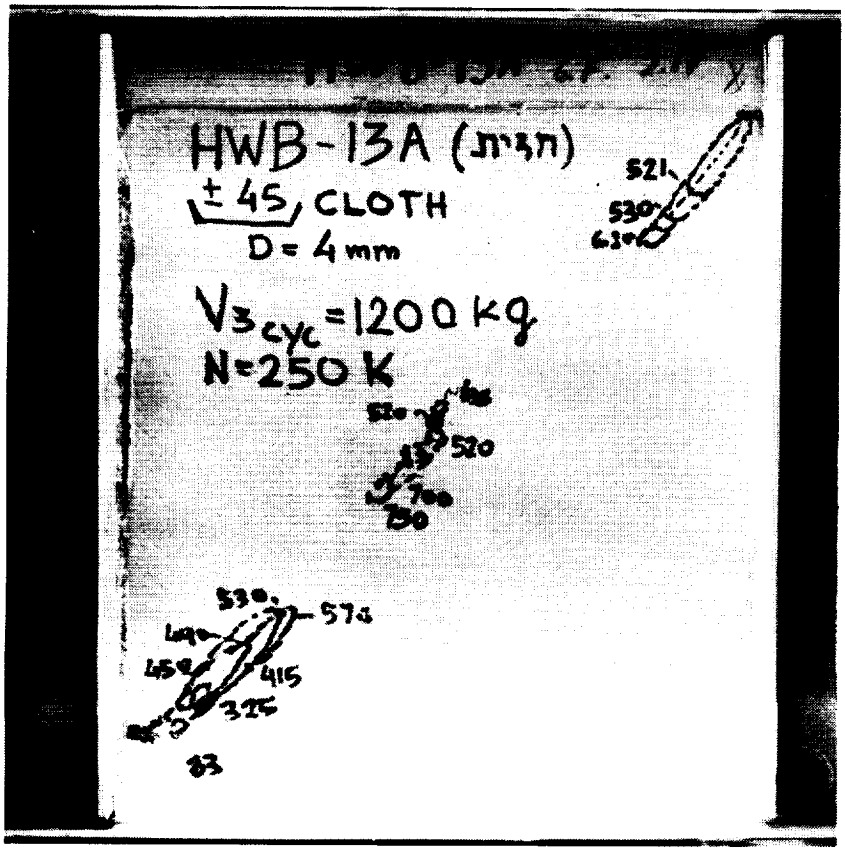


Figure 4. Fatigue failure of a graphite/epoxy shear panel (HWB 13A), with a central hole of 4 mm diameter, after 250,000 cycles at V_{cyc}=1200 kg. The failure occurs as cracks along the tension diagonal, emanating from the stress concentrations at the corners, as in unperforated shear panels.