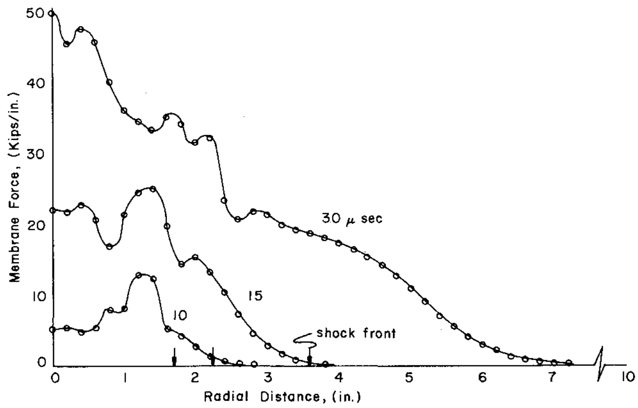

Fig. 3 Membrane force vs radial distance.

propagates along the plate ahead of the front as shown in Fig. 3. Due to the very high energy loading condition and the thinness of the plate, the maximum membrane and bending stresses were approximately 600 and 720 ksi, respectively, and occurred at the center of the plate between 30 and 35 μsec. These stresses are considerably larger than the aluminum can withstand, and considerable cracking and yielding will occur in this situation.

In this analysis the fluid-wall interaction has been neglected entirely, and the response of the wall was computed using the in vacuo structural response equations and the incident pressure. The interaction of the wall and the fluid is a complex phenomenon in which the fluid pressure acting on the wall is a function of the wall motion. There have been many studies of this interaction process for the condition of a flat plate vibrating against a fluid and a submerged shell engulfed by a pressure pulse, where it is assumed that the fluid satisfies the linearized wave equation. A separation of the structure equations from the fluid equations, a considerable simplification of the problem, can be accomplished by applying the so-called piston theory where the fluid response is assumed to be one-dimensional in space normal to the wall. Several studies have been conducted that evaluate the piston theory in specific fluid-structure interaction problems. A summary of these analyses is given in Ref. 2. The results presented in Ref. 2 indicate that the accuracy of the piston theory approximation depends upon the wave lengths involved; hence it depends upon the particular structure and incident pressure arrangement.

Further studies are planned to consider the effects of the fluid-wall interaction. In particular, damping effects will be put in the SATANS code and the applicability of the piston theory will be determined for both the shock phase and the cavity phase of hydraulic ram. Experiments also are being conducted to determine the fluid shock wave position as a function of time using shadowgraph techniques. The percentage of the initial projectile energy lost during the shock phase and the shock wave decay coefficient also will be determined for various entry wall-projectile combinations. These data will be used to substantiate the entry wall incident pressure loadings. Follow-on experiments are being planned to simultaneously obtain holographic interferograms of the fluid and wall to determine wall motion. These studies will yield an accurate theory which predicts entry wall motion and stresses. This information will enable the engineer to predict the vulnerability of various tank designs to the shock phase of hydraulic ram.

References

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Optimal Skin Thickness Variations for Active Cooled Panels

R. D. Wagner*

NASA Langley Research Center, Hampton, Va.

Nomenclature

C = constant in equation for skin thickness
k = material thermal conductivity
N = exponent in equation for skin thickness
$\dot{q}$ = aerodynamic heat transfer rate
S = half-width of panel section between coolant passages
T = skin temperature
V = volume of skin between coolant passages
ΔT = skin temperature change from panel section midpoint to coolant passage
τ = skin thickness

Subscripts

o = constant skin thickness value
N = panel section midpoint value for τ, or panel section midpoint temperature minus coolant passage temperature for ΔT

ACTIVE cooling of the airframe using the hydrogen fuel heat sink is a promising innovation for practical, long-lived structures for hypersonic aircraft. An attractive active cooling system is an internal convective cooling system which uses a secondary fluid circulated through panel passages to transfer the structure heat load to a centrally located hydrogen fuel heat exchanger.[1] The unit weight of this system structure depends in part upon the desired mean structure temperature and the allowable maximum skin temperature which occurs midway between coolant passages. The purpose of this Note is to show that a potential weight reduction can be achieved by varying the skin thickness and thereby minimizing the skin temperature change between coolant passages.

For the section of a panel illustrated in Fig. 1, if one assumes one-dimensional heat flow with constant thermal properties and sections that are long compared to their width, a simple heat balance for a uniform aerodynamic heat load, $\dot{q}$, gives,

$$\Delta T = T(0) - T(S) = \int_0^S \frac{\dot{q}}{k}\frac{x}{\tau}dx \qquad (1)$$

For a panel with constant thickness, τ_0, there results $\Delta T_0 = \dot{q}S_0^2/(2k\tau_0)$. We now ask the question: what thickness variation will yeild a minimum ΔT for a constant skin weight (or volume)? This is a trivial problem in the calculus of variations with the results, $\tau/\tau_0 = (3/2)(S_0/S)(x/S)^{1/2}$ and $\Delta T_{\min} = (4/9)(\dot{q}/k)(S^3/V)$. For $S = S_0$, $\Delta T_{\min}/\Delta T_0$ is then equal to 0.889. Hence, an 11% reduction in ΔT is achieved, but this result is impractical since the skin thickness must be zero at $x = 0$. To determine if a comparable reduction in the temperature change across the panel section can be obtained for other τ variations with nonzero values of τ, the integral, Eq. (1) was evaluated for a class of thickness variations, $\tau = \tau_N[1 + C(x/S)^N]$ with

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*Aerospace Technologist, Hypersonic Aircraft Systems Research Branch, Hypersonic Vehicles Division.

$C = (N + 1)(V/S\tau_N - 1)$. For these skin thickness variations,

$$\frac{\Delta T_N}{\Delta T_0} = 2(S/S_0)^2(\tau_0/\tau_N)\int_0^1 \frac{\xi d\xi}{1 + (N+1)[(V/V_0)(S_0/S)(\tau_0/\tau_N) - 1]\xi^N} \quad (2)$$

These results are shown in Fig. 1 for different values of the exponent, N, and for $V = V_0$ and $S = S_0$. For each N a thickness ratio, τ_n/τ_0, exists for which $\Delta T_N/\Delta T_0$ is a minimum. The linear variation, which would probably be the easiest to fabricate, gives as much as a 10.5% reduction in ΔT_N with a factor of five change in skin thickness across the panel section half width and $\tau_1 \approx \tau_0/3$.

These results indicate that maximum temperatures in active cooled panels can be reduced with nonuniform skin thickness of the panel. A system weight reduction is implied because for an allowable temperature change across the panel sections either the skin volume can be reduced for a given passage spacing (about 10.5% for $N = 1$), or the passage spacing can be increased for a given skin volume (about 3.5% for $N = 1$). Whether these small savings will be achievable will depend, however, upon the structural considerations of the effects of variable skin thickness and fabrication costs.

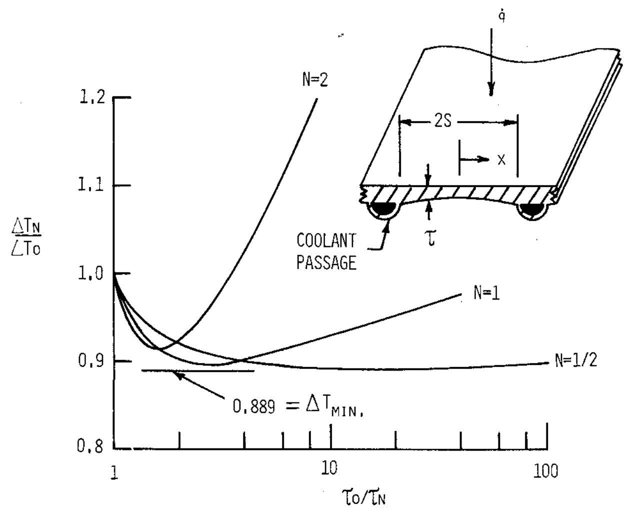

Fig. 1 The effect of nonuniform skin thickness on panel temperature change.

Reference

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Technical Comments

Comment on "Film Reinforced Multifastened Mechanical Joints in Fibrous Composites"

L. J. Hart-Smith*

Douglas Aircraft Company, McDonnell Douglas Corporation, Long Beach, Calif.

THE paper by Padawer[1] is concerned with a relatively new development in advanced composite materials, boron film. Being inplane isotropic instead of unidirectional as fibers are, it opens up possible structural advantages over filamentary composites.

While the boron/polyimide film has proved to be efficient in reinforcing basic laminates, there is not yet sufficient evidence to assess its potential as a hole reinforcement for practical aerospace construction. Accumulated evidence on bolted joints in advanced filamentary composites indicates that success with boron-film-reinforced bolted joints has yet to be demonstrated for conditions representative of current practice.

In order to explain how the work in the paper fits into the over-all picture, it is necessary to summarize the progress in advanced-composite bolted joints, in which certain characteristics have already been identified. First, ultimate static joint efficiencies are far below those developed by metal parts. The reason for this is that the composites are brittle while aluminum, titanium, and steel alloys exhibit considerable ductility in yielding locally to redistribute loads around a stress concentration. Second, the experimental joint strengths developed with mechanical fasteners in composites exceed significantly what would be expected according to a perfectly-elastic analysis. This gain in strength is due to the stress concentration relief afforded by even the limited (small) ductility exhibited by composites. For isotropic filament patterns (0°/45°/90°/−45°), this increase in strength ranges from a factor of 1.5 to one of about 3.0 for both HTS graphite and boron filaments in an epoxy matrix, the precise value depending on the joint geometry. Third, the stress concentration problem around bolt holes has been virtually completely eliminated when the longitudinal (0°) filaments in a strip of width 4 times the bolt diameter, in line with the bolt(s), have been replaced by S-glass filaments. The S-glass filaments have an ultimate elongation about 4 times as great as graphite and boron filaments. Since the average strain in the glass fibers is kept low by the adjacent advanced composite longitudinal fibers (outside the so-called softening strip), this relatively ductile region enables the gross laminate to be stressed far more highly than without such stress concentration relief. Indeed, in many such tests, failure has not been initiated at the bolt hole at all—the softening strips have been 100% effective. The bolt bearing stresses developed in composite laminates (both with

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*Senior Engineer Scientist, Structural Mechanics Subdivision.