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ESDU 95026

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Edge effects on the response of sandwich panels subjected to acoustic loading

Associated software: ESDUpac A9526
ESDUpac B9526

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THE PREPARATION OF THIS DATA ITEM

The work on this particular Item was monitored and guided by the Vibration and Acoustic Fatigue Committee which, under its original name of Acoustic Fatigue Panel, first met in 1966 and had the following membership:

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Dr I. Holehouse*	—	Rohr Industries Inc., Chula Vista, USA
Mr D.M.A.Millar	—	Short Brothers plc, Belfast
Mr H.F. Wolfe*	—	Wright-Patterson Air Force Base, Dayton, USA.

* Corresponding Member

The technical work in the assessment of the available information and the construction and subsequent development of the Data Item was carried out by

Mr R.F. Lambert	—	Head of Noise and Structural Dynamics Group.

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EDGE EFFECTS ON THE RESPONSE OF SANDWICH PANELS SUBJECTED TO ACOUSTIC LOADING

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EDGE EFFECTS ON THE RESPONSE OF SANDWICH PANELS SUBJECTED TO ACOUSTIC LOADING

1. NOTATION

		Units	
		SI	*British*
a, b	equivalent simply-supported panel length and width (see Sketch 1.1)	m	in
E_f, E_e	Young's moduli of face plate material and solid panel edge material respectively	N/m^2	lbf/in^2
f	panel response frequency (*i.e.* fundamental mode natural frequency)	Hz	Hz
h	sandwich panel core thickness	m	in
$L_{ps}(f)$	spectrum level of acoustic pressure at frequency f	dB*	dB*
l_1, l_2	solid panel edge dimensions (see Sketch 1.1)	m	in
T	ambient temperature	K	K
t	face plate thickness (inner and outer face plates of equal thickness)	m	in
t_a	thickness of face plate-to-core adhesive layer	m	in
t_e	thickness of solid panel edge member	m	in
t_i, t_o	thickness of inner and outer face plates respectively	m	in
w_n	maximum deflection of beam at mid span in *n*th mode	m	in
Y_A, Y_B	coordinates, relative to attachment line, defining strain gauge length ($Y_A > Y_B$), positive inwards (see Sketch 1.1)	m	in
z_e	distance from neutral axis to outer surface of solid panel edge	m	in
Δ	lateral displacement of panel edge	m	in
δ	viscous damping ratio in fundamental mode		

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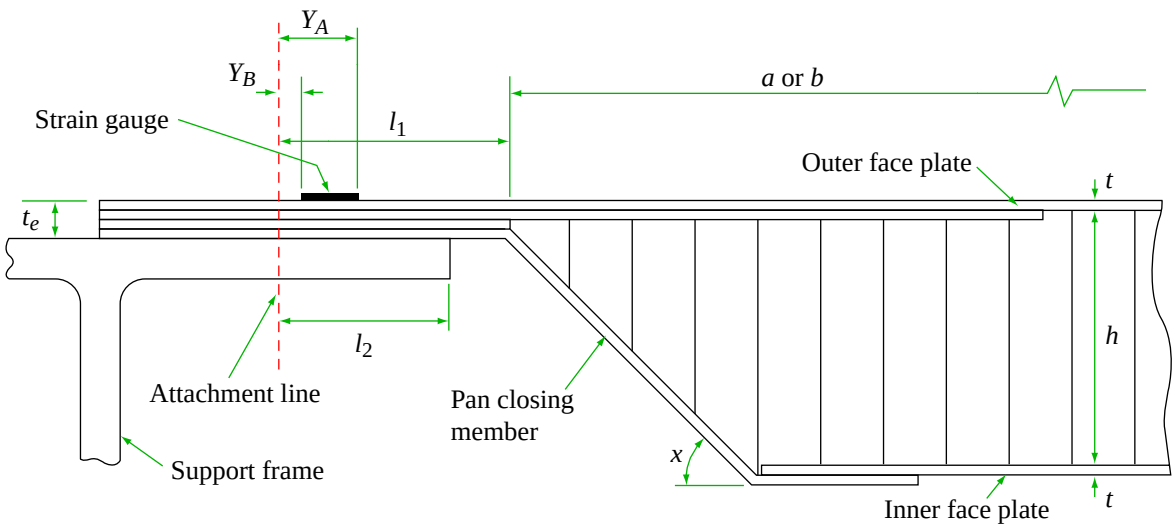
ρ_f, ρ_c, ρ_a	densities of face plate, panel core and adhesive layer respectively	kg/m^3	†
ν_f, ν_e	Poisson's ratio of face plate and solid panel edge respectively		
χ	bevelled edge angle (see Sketch 1.1)	deg	deg

* The reference pressure for sound levels expressed in decibels is 2×10^{-5} N/m^2 (*i.e.* 20 μ Pa) or 2.90×10^{-9} lbf/in^2 .

† See footnote on page 6.



Sketch 1.1 Panel edge detail

2. NOTES

2.1 General

This Item provides a means of estimating the rms surface strains on the solid edge members of a sandwich panel subjected to random acoustic loading. Also a means is provided for estimating the ratio of inner and outer face plate surface strains at the centre of a sandwich panel. The latter procedure is particularly for use with ESDU 72017* and ESDU 86024† where effects of the sandwich panel bevel edges are not considered. The estimation procedures are applicable to sandwich panels having isotropic face plate materials and, for edge strain evaluation, face plates of equal thickness. The sandwich panels considered are those having a bevelled edge that allows for a solid edge strip around the panel through which the panel is attached to the substructure. The data are applicable to flat panels of rectangular section that are initially unstressed.

If the panel edge design is not closely represented by that shown in Sketch 1.1 the results obtained using this Item should be used with caution. To illustrate the accuracy of the panel edge rms strain prediction method some comparisons between measured and estimated values are shown in Section 2.5.

* Stress response of flat or singly-curved sandwich panels with cores of zero flexural stiffness subjected to random acoustic loading.

† Estimation of rms strain in laminated face plates of simply-supported sandwich panels subjected to random acoustic loading. Including a simplified natural frequency prediction method.

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2.2 Method of Analysis

The methods of analysis are given in Derivations 3 to 5. The theory accounts for membrane strain that is introduced into the inner face plate by the rotation of the bevelled edges of the sandwich panel. The panels are assumed to be fixed at the panel edge attachment line. However, for the purpose of the analysis, the panel is replaced by an equivalent panel that is simply-supported at the base of the bevelled edges. It is assumed that the panel core is infinitely stiff in shear and that the panels are attached to stiff frames. Further, for the estimation of panel edge rms strains, it is assumed that the panel responds in its fundamental mode only and that the acoustic pressure is in phase over the whole of the panel. It is also assumed that the loading spectral density is constant over a range of frequencies including the predominant response frequency.

2.3 Edge Strain Location and Practical Strain Gauge Effects

The computer program, referred to as ESDUpac A9526*, supplied with this Item predicts the rms surface strain on the panel solid edge at the attachment line. The strain given is that at the centre of the panel longer side which is the peak edge strain location.

To allow a correlation of measured and predicted rms strain data, a facility is provided in the program to account for both the location and length of the strain gauge. This simulation of the strain gauge reading is necessary due to the short width of the panel solid edge member and the relatively high rate of change in rms strain over that width.

2.4 Strain Ratio at Centre of Panel

The ratio of surface strains on the inner and outer face plates at the centre of a sandwich panel may be estimated using the computer program referred to as ESDUpac B9526. The theory used for this program considers a beam with bevelled edges vibrating in the equivalent simply-supported mode shapes. For this analysis the isotropic face plates need not be of equal thickness and any mode having an odd number of half waves across the panel width may be considered. For stiff support frames, the membrane strain in the inner face plate leads to a higher rms strain in the inner face plate than on the outer face plate. The ratio of inner face plate strain to outer face plate strain is greatest for the fundamental mode. As the lateral flexibility of the support frame is increased the surface strain ratio decreases. This is illustrated in Sketch 2.1 where the surface strain ratio (inner surface strain/outer surface strain) is shown, for a typical panel, plotted against the ratio Δ/w_n for a range of values of t/h in the fundamental mode. In Derivation 3 it is suggested that the maximum lateral frame displacement is around 4 per cent of the panel displacement (*i.e.* the maximum value of $\Delta/w_n \approx 0.04$) in the fundamental mode for a typical honeycomb core sandwich panel.

* The full ESDUpac number has an appended V followed by two digits. The digits indicate the ESDUpac version number. For example, the full ESDUpac number for version 1.0 of ESDUpac A9526 is A9526V10. The version appendage will not be used when referring to ESDUpacs in the text of this Item.

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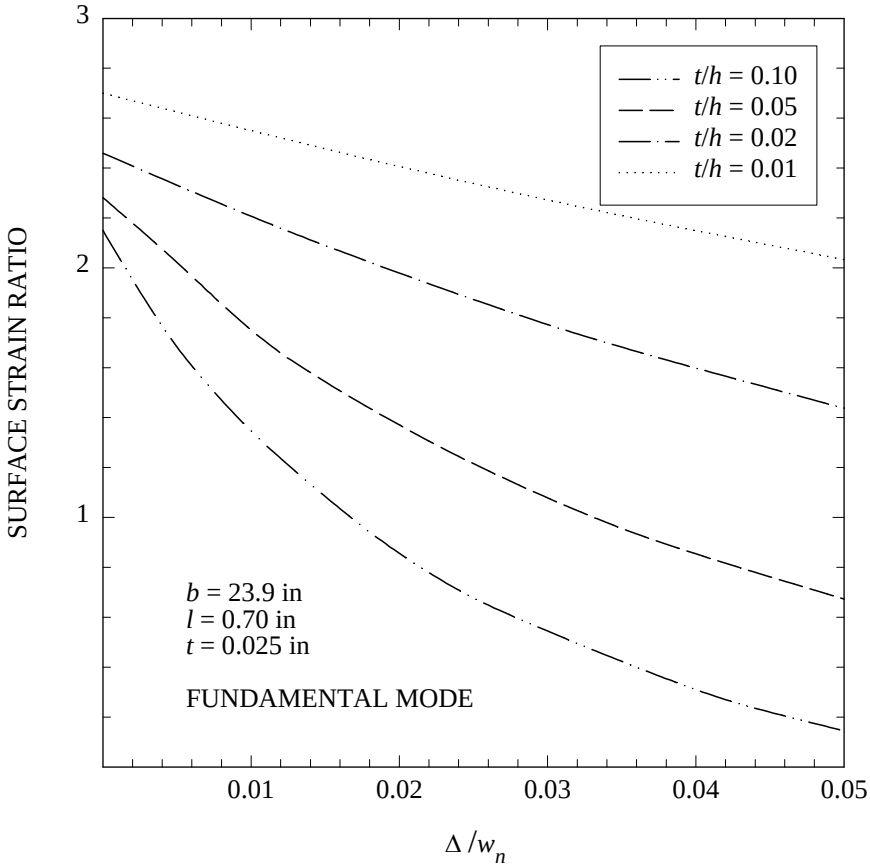

Sketch 2.1 Variation of Strain Ratio with Supported Frame Flexibility

2.5 Accuracy and Limitations of Data

The means of estimating the attachment line surface strains in the solid edge of sandwich panels under acoustic loading provided in this Item is constrained by the assumptions detailed in Section 2.2. The method of analysis is based on linear sandwich panel theory that is applicable to panels in which the displacements are small compared with the thickness. The assumptions that the panel responds only in its fundamental mode is usually a good approximation if the vibration modes are well separated in frequency. The theory is applicable to panels having a solid edge strip width that is small compared with the panel size. This criterion is satisfied if both $(\pi l_1/a)^2$ and $(\pi l_1/b)^2$ are small compared with unity.

The theory for the edge strain prediction is applicable to frames that are laterally stiff. This typically applies for test panels that are usually mounted on rigid support frames. In practical service structures the support frames are less rigid. As the lateral flexibility of the support frame increases the membrane strain induced by the rotation of the bevelled edge member is relieved. Consequently, the rms edge strains predicted by this Item will be conservative for flexible support frames.

In Figure 1 a comparison is made between the measured (Derivation 2) and estimated rms surface strains at the attachment line of a number of sandwich panels. Those panels had isotropic face plates of equal thickness and a wide range of panel geometries was tested. For many of the panels tested a fibreglass closing pan member was used. Appropriate allowances were made for the relative stiffnesses of the fibreglass closing member and the metal face plate and doublers when estimating the rms strains.

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