

ENDURANCE OF BONDED LAP JOINTS (ALUMINIUM ALLOY SHEET MATERIAL; PHENOLIC RESIN/VINYL POWDER GLUE, TENSILE LOADING)

1. NOTATION AND UNITS

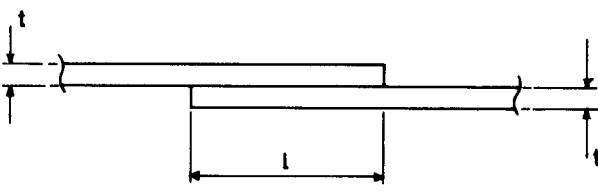
l	length of joint overlap	m	in
N	endurance		
q_a	nominal alternating shear stress in the glue	N/m ²	lbf/in ²
R	ratio of minimum to maximum load in cycle		
S_a	nominal alternating tensile stress in the sheet	N/m ²	lbf/in ²
S_m	nominal mean tensile stress in the sheet	N/m ²	lbf/in ²
t	thickness of each sheet	m	in
1 m	= 39.3701 in		
1 in	= 0.0254 m		
1 N/m ²	= $1.450\,38 \times 10^{-4}$ lbf/in ²		
1 lbf/in ²	= $6.894\,76 \times 10^3$ N/m ²		

Both SI and British units are shown but any coherent system of units may be used.

2. NOTES

The results of 280 fatigue tests on lap joints in aluminium alloy sheet materials bonded with a phenolic resin/vinyl powder glue to DTD 775 have been analysed to give curves of S_a against N .

The ranges of values of the main dimensions of the joints are given below with an edge view of a typical lap joint.

$$\begin{aligned}
 l &= 0.375 \text{ to } 1.96 \text{ in} \\
 t &= 0.033 \text{ to } 0.082 \text{ in} \\
 l/t &= 5.85 \text{ to } 29.5
 \end{aligned}$$


The sheet material, all of which was clad, was either naturally aged Al-Cu-Mg alloy (2024-T3 type) or artificially aged Al-Zn-Mg (7075-T6 type). The sheets were pickled in accordance with DTD 915A before bonding. The bonding agent consisted of Redux K-6 liquid with Redux powder. The bonds were cured at temperatures between 142 and 160°C for 15 to 30 minutes under pressures of 100 to 220 lbf/in².

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The loading corresponded with values of R between zero and 0.22 but R was about 0.1 in the majority of cases. Test temperature was about 15°C.

Each of the two figures shows mean endurance curves for a range of l/t and two values of t . The limits of the central 90 per cent of the data are also indicated. A conversion chart gives the average shear stress in the glue for a given tensile stress in the sheet and l/t , that is,

$$q_a = S_a \frac{t}{l}.$$

The curves given in the figures have been derived in the following manner. The stress analysis given in Derivation 1 was applied to the experimental data. In tests that ended in glue failure, the endurance was found to depend primarily on the maximum elastic theory shear stress in the glue, while for tests that ended in sheet failure, the endurance depended on the maximum tensile stress in the sheet. By means of the same stress analysis, the combined experimental data in terms of theoretical maximum stresses were converted to equivalent nominal stresses for a convenient range of practical joint dimensions.

For any given joint dimensions, the average strength of the joint is determined by the lower of the two curves for glue and sheet failure at the required endurance. The upper of the two curves indicates the average strength that would have been achieved if the alternative type of failure had not occurred. The considerable scatter of the strength properties implies that both types of failure may occur even though the average strength of the glue and sheet are different. Whether failure occurs in the glue or in the sheet depends on sheet thickness; for $t = 0.064$ in, both types of failure are equally probable in the high endurance region.

Unless the maximum tensile stress in the sheet approaches the proof stress of the material the failure of the bond is independent of the type of alloy used in the sheet. In the present results, no significant difference was found between the fatigue strengths of the two types of alloy when failure occurred in the sheet. One set of curves thus represents both types of alloy.

Ambient temperature has a marked effect on the fatigue strength of bonded joints. The curves in this Item are valid for temperatures between zero and 50°C approximately. Above this temperature the strength of the adhesive declines at an increasing rate. The loss of strength may be alleviated by an extended curing period. At temperatures around – 50°C the fatigue strength can be 15 per cent higher than indicated by the curves.

Tests made with various mean stress levels show that for glue failures the effect of mean stress on fatigue strength is negligible within the practical range, while for sheet failures the normal trend for aluminium alloy materials is observed.

All the data on which this Item is based were obtained from specially prepared simple specimens tested under laboratory conditions. When using this information in practice the following qualifications should be noted.

The strength of a bonded joint is critically dependent on adequate process control at all stages of manufacture; the scatter of strength of production joints may be greater than indicated on this Item.

As may be seen by comparison of this Item and Item No. Fat E.05.07, the fatigue strength of a bonded joint depends markedly on the local stress distribution. Consequently the behaviour of bonded joints of other geometry, for example, with multiple laminations, cannot be inferred from the present data. It should also be noted that the load concentration associated with “safety fastenings” (for example, widely-pitched rivets to prevent peeling) can substantially reduce the fatigue strength of a bonded joint.