

FATIGUE STRENGTH OF CRUCIFORM AND OTHER FILLET WELDED JOINTS IN ALUMINIUM ALLOYS

1. INTRODUCTION

This Item provides data on the fatigue strength of metal-inert-gas (MIG) cruciform and other fillet welded joints in aluminium alloys, which are extensively used in welded structures and beams. The joints covered by this Item are shown in Table 5.1 together with a full description.

A general description and analysis of the welding of aluminium alloys, including metallurgical and thermal effects, is given in Data Item No. 91039*, which also includes an appendix which gives details of chemical composition, typical filler alloys and the standard aluminium alloy and temper designation system.

2. NOTATION

Both SI and British units are quoted.

f_t	tensile strength	N/m ²	lbf/in ²
N	endurance		
R	stress ratio, S_{min}/S_{max}		
S	nominal applied stress in absence of crack	N/m ²	lbf/in ²
S_a	alternating applied stress (half range) in loaded plate	N/m ²	lbf/in ²
S_m	mean applied stress in loaded plate = $(1 + R)S_{max}/2$	N/m ²	lbf/in ²
S_{max}	maximum value of S in loaded plate	N/m ²	lbf/in ²
S_{min}	minimum value of S in loaded plate	N/m ²	lbf/in ²
S_y	yield stress (0.2 per cent proof unless otherwise stated)	N/m ²	lbf/in ²
t	nominal thickness of loaded plate	m	in

3. FATIGUE STRENGTH

3.1 Interpretation of Data

Fatigue strength test data are presented for cruciform and other fillet welded joints in the as-welded state and with some post-weld treatments. Design codes such as BS 8118[†] (Reference 8) provide fatigue design curves that should be conservative. A presentation of the available data, including the various factors affecting fatigue strength, allows a better understanding of the fatigue behaviour of welded joints and may be used in the analysis of failures. Such data are presented in this Data Item with a mean curve drawn through each set, not as a design curve, but simply to indicate the trend. However, the available data are

* Data Item No. 91039 "Static and fatigue strength of butt welded joints in aluminium alloys".

[†] BS 8118 has recently replaced BS CP118 (Reference 7).

Issued August 1992

limited and can therefore only give a guide to the factors that influence the fatigue strength. Most of the factors that influence the fatigue strength of fillet welds in steel, such as the joint geometry and size, will also be relevant to aluminium welds. These influences are described for steel welds in Data Item No. 75016*.

3.2 Fatigue Data

The fatigue data are presented in Figures 1 to 31 with mean $S-N$ curves drawn through each set of data points. All joints are illustrated in Table 5.1. The mean curves take the form of straight lines where possible. The lower ends of these terminate at the value of $2S_a$ for the lowest data point signifying a break or the highest non-break data point if it appears higher. In this way, emphasis is given to actual failures. Table 5.2 details alloy composition and mechanical properties for each test material. All test details such as joint type, stress ratio, dimensions and test conditions are given for each curve in Table 5.3, together with a summary of mean fatigue strengths from the curves at endurance of 10^6 and 10^7 cycles. It must be stressed that these values give only an indication of the mean fatigue strength and that confidence limits cannot be given due to the nature and quantity of the test data.

The fatigue tests were carried out on test coupons, all of which were plate or sections less than 15 mm (0.6 in) in thickness. Figures 1 to 20 cover load-carrying and non-load-carrying transverse and longitudinal fillet welded joints, including cover-plate and cruciform joints (labelled A to M). Figures 21 to 31 give data for single and double lap and tee fillet welded joints (labelled N1, N2, P1, P2 and P3). The fatigue strengths of each joint type are shown collectively in summary Figures 32 and 33 for alloy 5083 and stress ratios of 0 and -1 respectively. Summaries of the fatigue strength mean curve values from these figures are given in Tables 5.4 and 5.5. Scatter bands are also given in Figures 34 and 35 for each joint in all materials at a stress ratio of 0.

The stresses quoted for each joint are the nominal stresses at the section where failure occurred, except for joints C, D, N1, P1 and P2. In those cases, failure occurred in the weld throat; however the weld sizes were not reported. The stresses quoted are therefore the cover-plate stress for joints C and D, the leg stress for joints P1 and P2, and the stress in the main plates for joint N1, or in the 6061 alloy plate for N1 joints between dissimilar alloys. The plate in which the quoted stress was acting is indicated for each joint in Table 5.1 by a dashed line.

3.3 Factors Influencing the Fatigue Strength

There are many factors that will influence the fatigue strength of welded joints. Most result from the fatigue strength of the plate in the region of the weld toe which is in turn influenced by the depth of weld penetration, weld bead size or excessive porosity. In consequence of the many factors, there will always be a large scatter in welded joint fatigue strength data. For the joints and materials in this Data Item, parent material tensile strength was not a significant factor in determining welded joint fatigue strength. This can be seen in Figures 36a and 36b which show the variation in fatigue strength with parent material tensile strength at 10^5 and 10^7 cycles respectively. However, parent material tensile strength may be significant in fatigue at high stress levels and short lives, for example 10^3 cycles, and will influence the static strength of welded joints.

The following sections discuss the main factors that affect the fatigue strength of cruciform and other fillet welded joints.

3.3.1 Joint configuration and loading

The most significant factor affecting fatigue behaviour is the geometry of the joint configuration which will give rise to stress concentrations. The higher the magnitude of stress concentration, the lower the

* Data Item No. 75016 "Fatigue strength of transverse fillet and cruciform butt welds in steels".

resulting fatigue strength will be. The effect of joint configuration is shown clearly in Figures 34 and 35 where fatigue strength scatter bands are given for each joint type in all materials at a stress ratio of 0. The data presented are mainly for specimens under axial load; however, Figure 31 presents data for tee fillet welded joints under bending load. No data are reported for the case of reinforcing cover-plates on beams loaded in bending.

The welds in cruciform and other fillet welded joints can be either load-carrying or non-load-carrying. The summary Figure 33 gives mean fatigue strength curves from the data for 5083 alloy (extracted from Figures 1 to 31) for load-carrying joints A and F and non-load-carrying joints B, J, K, L and M at a stress ratio of -1 . Leaving aside weld failures, it can be seen from Tables 5.4 and 5.5, and from the general data, that joints with transverse welds had a higher fatigue strength than joints with longitudinal welds (due mainly to stress concentrations at the ends of longitudinal welds). Also, within each group, joints with non-load-carrying welds tended to have a higher fatigue strength than joints with load-carrying welds.

The effect of offset between plates is shown in Figures 1 to 3 for joint A. Due to the bending stresses induced, the offset joints generally had a lower fatigue strength than those in which the plates were properly aligned.

A description of the fatigue behaviour of each joint type follows.

3.3.1.1 Cruciform (A and B)

All cruciform joints reported have four transverse welds which can either be load-carrying (joint A) or non-load-carrying (joint B). Joints of types A and B lie in the high strength band of fillet welded joints reported here owing to the geometry and direct load path through the joint.

3.3.1.2 Cover-plate (C to H)

Welds in the cover-plate joints reported are load-carrying and can be transverse or longitudinal. In general, joints with transverse welds have a higher fatigue strength as longitudinal welds usually introduce high stress concentrations at the weld ends, and so lead to lower fatigue strengths.

3.3.1.3 Fillet attachment (J to M)

Any attachment to a stressed plate causes stress concentrations and the effect of this should not be under-estimated. Non-load-carrying joints, J, K, L and M, give rise to more severe stress concentrations than the load-carrying cruciform joint, A, so giving them a lower fatigue strength (see Figure 33).

3.3.1.4 Lap (N1 and N2)

Lap joints contain transverse, load-carrying welds but generally have a low fatigue strength due partly to the additional bending stresses induced by the geometry of the joint.

3.3.1.5 Tee (P1 to P3)

The tee fillet welded joints for which data are presented in this Data Item have load-carrying transverse welds except for joint P3 in which the leg is a non-load-carrying attachment to a plate subject to out-of-plane bending. Double fillet welded tee joints generally have a high fatigue strength owing to the direct load path, and have similar fatigue strengths and geometry to the cruciform joints. However, single fillet welded tee joints have a poor fatigue strength owing to the asymmetry introduced which results in bending stresses.

One set of data is given for tee joint P3 under bending load. This joint has a higher fatigue strength than

the tee joints under axial load because the attachment is non-load-carrying and the stresses quoted are the plate bending stresses.

3.3.2 Size effect

Test coupons may not contain the high residual stresses present in joints containing elements with greater thickness. These stresses arise due to a large temperature gradient through the material thickness during the welding process (see Section 3.3.4). Another effect of size, detailed in Data Item No. 87016*, is that for the same initial size of weld toe defect, a larger scale joint will experience increased crack propagation, thereby reducing fatigue life. **For both of these reasons, fatigue test data on small scale or thin specimens tend to be optimistic in the prediction of fatigue life of thicker sections or welded fabrications.**

3.3.3 Weld profile and size

Table 5.1 shows typical locations of cracks resulting from fatigue loading of welded joints. For the tests reported in this Data Item, fatigue failure occurred in one of the following two ways. Firstly, cracks initiated from small defects, typically up to 0.5 mm (0.02 in) in depth, present at the stress concentration at the weld toe and propagated through the plate (for example, Table 5.1, joints A and G). Secondly, if there was a small weld throat, defects initiated cracks at the weld root that grew outwards through the weld metal (see Table 5.1, joints C and D).

The stress concentration at the weld toe is caused by the geometry of the weld bead, and its magnitude depends primarily on the angle formed between the parent and weld material. In general, the smoother the transition from the parent to weld material, the lower the stress concentration and, consequently, the higher the fatigue strength. The process of tungsten-inert-gas (TIG) dressing, described in Section 3.3.6, smooths the weld profile at the toe, improving the fatigue strength of welded joints.

3.3.4 Residual stresses

Welding induces a highly localised system of residual stresses due to local thermal expansion, plastic deformation and subsequent shrinkage on cooling. The pattern of residual stress is dependent on the material thickness and the number of weld passes used, while their magnitude can approach the yield strength of the material. In thick material of the order of 20 mm (0.8 in) or more, large temperature gradients will be set up during welding, leading to more severe residual stress levels. Components that are constrained may also develop severe residual stresses as contraction after welding is restricted. Such residual stresses rarely arise in small test coupons.

It is difficult to evaluate residual stress levels and therefore their resulting effect on fatigue strength. The approach used by Design Codes such as BS 8118 is to assume that residual stress levels will be high enough to cause localised yielding at the weld toe, so forming a yield limited condition.

3.3.5 Effects of stress ratio, R

The stress ratio, R , indicates the applied mean stress level. For the fatigue tests reported, either R or the mean stress S_m , remained constant. For the latter, the equivalent range of R is shown in each figure. Figures 1 to 3 and 13 to 15 each demonstrate the effect of applied mean stress, the fatigue strength decreasing markedly as the mean stress increases. Figures 4 to 6 show a less marked effect of increased mean stress for non-load-carrying cruciform joints than for the load-carrying joints of Figures 1 to 3.

The $R = -1$ ratio was obtained by axial load push-pull except in the single case of Figure 31, joint P3, where the $R = -1$ ratio was obtained by bending and this gives a different stress distribution from the

* Data Item No. 87016 "Effect of size on fatigue strength of steel components".

axial tests.

3.3.6 Post-weld improvements

Test data for toe peened cruciform joints and peened transverse fillet cover-plate joints have been reported in Figures 7, 10 and 11. Toe peening increases the fatigue strength of welds by inducing surface residual compressive stresses, thereby counteracting the existing tensile residual stresses resulting from welding. Toe profile improvement and work hardening may also result from toe peening. Figure 7 shows test data for as-welded and toe peened cruciform joints, where a definite improvement in fatigue strength is present at all lives. It is seen from Figures 10 and 11 that peening is more effective if carried out after the mean load has been applied to the joint, particularly at low loads and low stress ratios.

Figure 12 shows the fatigue strength improvement achieved by TIG (tungsten-inert-gas) dressing the fillet welds of a transverse cover-plate joint. This treatment involves remelting the toe regions of welds with the aim of improving their profile so that the stress concentration is reduced where the weld bead meets the parent material. TIG dressing has advantages in that it can be applied during the fabrication of welded components or structures and changes to weld profiles can be inspected visually. The weld profile can also be modified by toe grinding.

4. DERIVATION AND REFERENCES

4.1 Derivation

This section lists selected sources that have assisted in the preparation of this Item.

- | | | |
|----|----------------------------------|---|
| 1. | GUNN, K.W.
MCLESTER, R. | Fatigue strength of welded joints in aluminium alloys. <i>British Welding Journal</i> , pp. 634-649, December 1962. |
| 2. | PERSON, N.L. | Fatigue of aluminium alloy welded joints. <i>Welding Research Supplement</i> , Vol. 50, Part 2, pp. 77-87, 1971. |
| 3. | MONTEMARANO, T.W.
WELLS, M.E. | Improving the fatigue performance of welded aluminium alloys. <i>Weld Journal (London)</i> , Vol. 59, Part 6, pp. 21-28, UK, 1980. |
| 4. | POLMEAR, I.J. | Effects of peening on the fatigue performance of aluminium alloy fillet welds. <i>Australian Welding Research</i> , Vol. 8, pp. 37-41, February 1980. |
| 5. | OHNO, H.
KOIBUCHI, K. | Improvement of fatigue strength of aluminium alloy welded joints by toe peening. <i>Welding Institute of Japan, collected Papers</i> , Vol. 3, pp. 182-188, 1985. |
| 6. | POLMEAR, I.J. | Post-weld surface treatments to improve fatigue properties of aluminium weldments. <i>Australian Welding Research</i> , Vol. 31, pp. 64-69, 1986. |

4.2 References

The references given are recommended sources of information supplementary to that in this Item.

- | | | |
|----|-----|--|
| 7. | BSI | Code of Practice CP 118. The structural use of aluminium. British Standards Institution, UK, 1969. |
| 8. | BSI | BS 8118. Structural use of aluminium. Part 1: Code of practice for design, UK, 1992. |



5. DATA

TABLE 5.1 Joint Descriptions and Geometry

Section over which stress S is calculated is shown by a dashed line. Failure locations indicated

Description	Classification	Geometry
1. Cruciform — Transverse Welds — Load-carrying Welds Non-load-carrying Welds	A	
	B	
2. Cover-plate — Load-carrying Welds — Transverse Welds — Full Width Cover-plate Narrow Cover-plate Longitudinal Welds — Plate Angle Channel	C, E	
	D	
	F	
	G	
	H	

TABLE 5.1 Joint Descriptions and Geometry (continued)

Description	Classification	Geometry
3. Fillet Attachment—Non-load-carrying Welds — Longitudinal Welds - Wide Plate - Narrow Plate - Edge Attachment - Cross Plate	J K L M	
4. Lap — Load-carrying Welds — Transverse Welds - Single Fillet - Double Fillet	N1 N2	
5. Tee - Axial Load — Load-carrying Welds - Single Fillet - Double Fillet - Bending Load — Non-load-carrying — Double Fillet Attachment	P1 P2 P3	



TABLE 5.2 Alloy Compositions and Mechanical Properties

Alloy and temper (new BS designations)	Figure Numbers	Thickness mm (in)	Content (per cent)							Measured tensile properties			Alloy and temper (old BS designations as tested)
			Cu	Mg	Si	Fe	Mn	Cr	Ti	0.1% proof stress MN/m ² (10 ³ lbf/in ²)	Tensile strength MN/m ² (10 ³ lbf/in ²)	Elongation on 50.8 mm (per cent)	
5052-H32	21, 22, 25, 26	4.8 (0.19)	0.05	2.49	0.11	0.28	0.04	0.2	0.02	179 (26)	236 (34)	15.2	–
5083-F*	1, 4, 8, 9, 13	6.4 (0.25)	0.028	4.31	0.12	0.25	0.61	–	0.008	253 (37)	333 (48)	16.5	NP 5/6 M
		12.7 (0.5)	0.025	4.10	0.13	0.27	0.56	–	0.008	171 (25)	306 (44)	23.5	
5083-F	1, 4, 8, 13, 17, 18	6.4 (0.25)	0.023	4.23	0.09	0.20	0.82	0.10	0.006	236 (34)	332 (48)	17.5	NP 8 M
		12.7 (0.5)	0.013	4.52	0.12	0.22	0.79	0.09	0.0005	173 (25)	326 (47)	21	
5083-H113	23, 24, 27	9.5 (0.37)	0.07	4.42	0.14	0.28	0.07	0.1	0.02	269 (39)	358 (52)	14.1	–
5083-H321	28, 29	9.5 (0.37)	0.08	4.4	0.14	0.24	0.67	0.11	0.02	210 (30)	339 (49)	20.7	–
5251A-H14	2, 5, 8, 9, 14, 19	6.4 (0.25)	0.036	2.16	0.15	0.31	0.37	–	0.008	207 (30)	256 (37)	13	NS 4½ H
5251A-F	2, 5, 14	12.7 (0.5)	0.027	2.18	0.14	0.31	0.36	–	0.009	133 (19)	207 (30)	29	NP 4 M
6061-T6	22, 24, 26, 29	6.4 (0.25)	0.23	0.99	0.73	0.52	0.07	0.25	0.01	298 (43)	316 (46)	15.5	–
6082-T6	3, 6, 8, 9, 15, 16, 17, 20	6.4 (0.25)	0.018	0.63	0.99	0.30	0.56	–	0.046	287 (42)	314 (46)	15	HP 30 WP
		12.7 (0.5)	0.02	0.65	1.00	0.30	0.54	–	0.040	283 (41)	312 (45)	17.5	HP 30 WP
7005-T4	7	6.0 (0.24)	0.25	1.25	0.12	0.23	0.59	0.2	–	265 (38)	412 (60)	16	–
7039-T61	30	9.5 (0.37)	0.05	2.51	0.08	0.21	0.28	0.17	0.03	345 (50)	402 (58)	17.1	–

* Not exact equivalent: old BS specifies 0.05% < Cr < 0.25% .


TABLE 5.3 Test Details for Figures 1 to 31 with Summary of Mean Fatigue Strengths from Curves

Figure Number	Joint type	Alloy and temper* (new BS designations)	$t^\dagger$ mm (in)	Parent material S_y MN/m ² (10 ³ lbf/in ²)	R (Range tested)	Test conditions‡	Fatigue strength, $2S_a$ MN/m ² (10 ³ lbf/in ²)			
							R = 0 curve		R = -1 curve	
							10 ⁶ cycles	10 ⁷ cycles	10 ⁶ cycles	10 ⁷ cycles
1	A, cruciform	5083-F** and 5083-F	6.4 (0.25)	253 (37)	-1, 0 to 0.85	As-welded, varying mean stress	56 (8.1)	33 (4.8)	86 (12)	–
			12.7 (0.5)	173 (25)						
2	A, cruciform	5251A-H14 to 5251A-F	6.4 (0.25)	207 (30)	-1, 0 to 0.85	As-welded, varying mean stress	52 (7.5)	–	80 (12)	50 (7.3)
			12.7 (0.5)	133 (19)						
3	A, cruciform	6082-T6	6.4 (0.25)	287 (42)	-1, 0 to 0.83	As-welded, varying mean stress	56 (8.1)	30 (4.4)	88 (13)	57 (8.3)
			12.7 (0.5)	283 (41)						
4	B, cruciform	5083-F** and 5083-F	6.4 (0.25)	253 (37)	-1, 0, 0.48 to 0.83	As-welded, varying mean stress	74 (11)	–	88 (13)	51 (7.4)
			12.7 (0.5)	173 (25)						
5	B, cruciform	5251A-H14 to 5251A-F	6.4 (0.25)	207 (30)	-1, 0, 0.48 to 0.82	As-welded, varying mean stress	74 (11)	–	102 (15)	–
			12.7 (0.5)	133 (19)						
6	B, cruciform	6082-T6	6.4 (0.25)	287 (42)	-1, 0, 0.48 to 0.8	As-welded, varying mean stress	78 (11)	–	95 (14)	58 (8.4)
			12.7 (0.5)	283 (41)						
7	B, cruciform	7005-T4	6.0 (0.24)	265 (38)	0	As-welded	110 (16)	73 (11)	–	–
						Toe peened	170 (25)	–	–	–
8	C, cover-plate	5083-F** and 5083-F	6.4 (0.25)	253 (37)	0	As-welded	38 (5.5)	–	–	–
			12.7 (0.5)	173 (25)						
8	C, cover-plate	5251A-H14	6.4 (0.25)	207 (30)	0	As-welded	35 (5.1)	–	–	–
			12.7 (0.5)	–						
8	C, cover-plate	6082-T6	6.4 (0.25)	287 (42)	0	As-welded	35 (5.1)	–	–	–
			12.7 (0.5)	283 (41)						
9	D, cover-plate	5083-F**	6.4 (0.25)	253 (37)	0	As-welded	29 (4.2)	17 (2.5)	–	–
			12.7 (0.5)	171 (25)						

* Similar alloys have been grouped. For dissimilar joints, thicknesses correspond to the alloy on the same level.

† Where two thicknesses are given for a joint, the upper value is for the plate indicated by a dashed line in Table 5.1.

‡ All axial load except Figure 31 (bending), filler alloy 5356 used for all test data except Figure 30 (where filler used was 5039).

** Not exact equivalent to new BS designation: see Table 5.2, NP 5/6 M



TABLE 5.3 Test Details for Figures 1 to 31 with Summary of Mean Fatigue Strengths from Curves (continued)

Figure Number	Joint type	Alloy and temper* (new BS designations)	$t^\dagger$ mm (in)	Parent material S_y MN/m ² (10 ³ lbf/in ²)	R (Range tested)	Test conditions‡	Fatigue strength, $2S_a$ MN/m ² (10 ³ lbf/in ²)			
							R = 0 curve		R = -1 curve	
							10 ⁶ cycles	10 ⁷ cycles	10 ⁶ cycles	10 ⁷ cycles
9	D, cover-plate	5251A-H14	6.4 (0.25)	207 (30)	0	As-welded	26 (3.8)	17 (2.5)	–	–
			12.7 (0.5)	–						
9	D, cover-plate	6082-T6	6.4 (0.25)	287 (42)	0	As-welded	20 (2.9)	12.5 (1.8)	–	–
			12.7 (0.5)	283 (41)						
10	E, cover-plate	5083-H321	9.5 (0.37)	–	0.54	As-welded	56 (8.1)	–	–	–
			6.4 (0.25)	–	0.54	Peened before loading	56 (8.1)	–	–	–
					0.54	Peened after loading	71 (10)	–	–	–
11	E, cover-plate	5083-H321	9.5 (0.37)	–	–0.35 to –0.68	As-welded	–	–	–	–
			6.4 (0.25)	–	–0.35 to –0.68	Peened before loading	110 (16)	–	–	–
					–0.35 to –0.68	Peened after loading	–	–	–	–
12	E, cover-plate	5083-H321	9.5 (0.38)	–	–0.3 to –0.66	As-welded	55 (8.0)	–	–	–
			6.4 (0.25)	–	–0.4 to –0.73	TIG dressed	100 (15)	–	–	–
13	F, cover-plate	5083-F** and 5083-F	6.4 (0.25)	253 (37)	–1, 0, –0.37 to 0.6	As-welded	29 (4.2)	17 (2.5)	39 (5.7)	–
			12.7 (0.5)	173 (25)						
14	F, cover-plate	5251A-H14 to 5251A-F	6.4 (0.25)	207 (30)	–1, 0, –0.44 to 0.77	As-welded	35 (5.1)	–	49 (7.1)	31 (4.5)
			12.7 (0.5)	133 (19)						
15	F, cover-plate	6082-T6	6.4 (0.25)	287 (42)	–1, 0, –0.18 to 0.9	As-welded	33 (4.8)	16 (2.3)	46 (6.7)	25 (3.6)
			12.7 (0.5)	283 (41)						
16	G, cover-plate	6082-T6	6.4 (0.25)	287 (42)	0	As-welded	27 (3.9)	13 (1.9)	–	–
			12.7 (0.5)	283 (41)						

* Similar alloys have been grouped. For dissimilar joints, thicknesses correspond to the alloy on the same level.

† Where two thicknesses are given for a joint, the upper value is for the plate indicated by a dashed line in Table 5.1.

‡ All axial load except Figure 31 (bending), filler alloy 5356 used for all test data except Figure 30 (where filler used was 5039).

** Not exact equivalent to new BS designation: see Table 5.2, NP 5/6 M.



TABLE 5.3 Test Details for Figures 1 to 31 with Summary of Mean Fatigue Strengths from Curves (continued)

Figure Number	Joint type		Alloy and temper* (new BS designations)	$t^\dagger$ mm (in)	Parent material S_y MN/m ² (10 ³ lbf/in ²)	R (Range tested)	Test conditions [‡]	Fatigue strength, $2S_d$ MN/m ² (10 ³ lbf/in ²)			
								$R = 0$ curve		$R = -1$ curve	
								10 ⁶ cycles	10 ⁷ cycles	10 ⁶ cycles	10 ⁷ cycles
17	H, cover-plate		5083-F	12.7 (0.5)	173 (25)	0	As-welded	–	17 (2.5)	–	–
17	H, cover-plate		6082-T6	12.7 (0.5)	283 (41)	0	As-welded	–	18 (2.6)	–	–
18	Fillet attachments	J	5083-F	6.4 (0.25)	236 (34)	–1	As-welded	–	–	50 (7.3)	–
		K	5083-F	6.4 (0.25)	236 (34)	–1	As-welded	–	–	50 (7.3)	–
		L	5083-F	6.4 (0.25)	236 (34)	–1	As-welded	–	–	74 (11)	–
		M	5083-F	6.4 (0.25)	236 (34)	–1	As-welded	–	–	32 (4.6)	–
19	Fillet attachments	J	5251A-H14	6.4 (0.25)	207 (30)	–1	As-welded	–	–	55 (8.0)	–
		K	5251A-H14	6.4 (0.25)	207 (30)	–1	As-welded	–	–	70 (10)	–
		L	5251A-H14	6.4 (0.25)	207 (30)	–1	As-welded	–	–	75 (11)	38 (5.5)
		M	5251A-H14	6.4 (0.25)	207 (30)	–1	As-welded	–	–	44 (6.4)	–
20	Fillet attachments	J	6082-T6	6.4 (0.25)	287 (42)	–1	As-welded	–	–	52 (7.5)	–
		K	6082-T6	6.4 (0.25)	287 (42)	–1	As-welded	–	–	52 (7.5)	–
		L	6082-T6	6.4 (0.25)	287 (42)	–1	As-welded	–	–	49 (7.1)	23 (3.3)
		M	6082-T6	6.4 (0.25)	287 (42)	–1	As-welded	–	–	47 (6.8)	–
21	N1 and N2, Lap		5052-H32	4.8 (0.19)	179 (26)	0	Single fillet	21 (3.0)	14 (2.0)	–	–
							Double fillet	21 (3.0)	–	–	–
22	N1 and N2, Lap		5052-H32 to 6061-T6	4.8 (0.19)	176 (26)	0	Single fillet	24 (3.5)	15 (2.2)	–	–
				6.4 (0.25)	298 (43)	0	Double fillet	22 (3.2)	14 (2.0)	–	–
23	N1 and N2, Lap		5083-H113	9.5 (0.37)	269 (39)	0	Single fillet	20 (2.9)	–	–	–
							Double fillet	17 (2.5)	–	–	–
24	N1 and N2, Lap		5083-H113 to 6061-T6	9.5 (0.37)	269 (39)	0	Single fillet	22 (3.2)	14 (2.0)	–	–
				6.4 (0.25)	298 (43)	0	Double fillet	20 (2.9)	–	–	–

* Similar alloys have been grouped. For dissimilar joints, thicknesses correspond to the alloy on the same level.

† Where two thicknesses are given for a joint, the upper value is for the plate indicated by a dashed line in Table 5.1.

‡ All axial load except Figure 31 (bending), filler alloy 5356 used for all test data except Figure 30 (where filler used was 5039).

92017

**TABLE 5.3 Test Details for Figures 1 to 31 with Summary of Mean Fatigue Strengths from Curves (continued)**

Figure Number	Joint type	Alloy and temper* (new BS designations)	$t^\dagger$ mm (in)	Parent material S_y MN/m ² (10 ³ lbf/in ²)	R (Range tested)	Test conditions [‡]	Fatigue strength, $2S_a$ MN/m ² (10 ³ lbf/in ²)			
							$R = 0$ curve		$R = -1$ curve	
							10 ⁶ cycles	10 ⁷ cycles	10 ⁶ cycles	10 ⁷ cycles
25	P1 and P2, tee	5052-H32	4.8 (0.19)	179 (26)	0	Single fillet	15 (2.2)	11 (1.6)	–	–
						Double fillet	63 (9.1)	43 (6.2)	–	–
26	P1 and P2, tee	5052-H32 to 6061-T6	4.8 (0.19)	179 (26)	0	Single fillet	21 (3.0)	14 (2.0)	–	–
			6.4 (0.25)	298 (43)	0	Double fillet	66 (9.6)	44 (6.4)	–	–
27	P1 and P2, tee	5083-H113	9.5 (0.37)	269 (39)	0	Single fillet	14 (2.0)	–	–	–
						Double fillet	50 (7.3)	30 (4.4)	–	–
28	P1 and P2, tee	5083-H321	9.5 (0.37)	210 (30)	0	Single fillet	24 (3.5)	15 (2.2)	–	–
						Double fillet	77 (11)	–	–	–
29	P1 and P2, tee	5083-H321 to 6061-T6	9.5 (0.37)	210 (30)	0	Single fillet	35 (5.1)	–	–	–
			6.4 (0.25)	298 (43)	0	Double fillet	66 (9.6)	40 (5.8)	–	–
30	P1 and P2, tee	7039-T61	9.5 (0.37)	345 (50)	0	Single fillet, filler 5039	19 (2.8)	–	–	–
						Double fillet, filler 5039	50 (7.3)	27 (3.9)	–	–
31	P3, tee	5086-H116	6.4 (0.25)	–	–1	Base metal, bending load	–	–	260 (38)	210 (30)
						Double fillet, bending load	–	–	110 (16)	80 (12)

* Similar alloys have been grouped. For dissimilar joints, thicknesses correspond to the alloy on the same level.

† Where two thicknesses are given for a joint, the upper value is for the plate indicated by a dashed line in Table 5.1.

‡ All axial load except Figure 31 (bending), filler alloy 5356 used for all test data except Figure 30 (where filler used was 5039).

**TABLE 5.4 Comparison of Mean Fatigue Strengths from Curves for Joints in 5083 Alloy at $R = 0$ (from Figure 32)**

Presented in order of decreasing strength

Joint classification, type	Alloy and temper (new BS designations)	Transversely (T) or longitudinally (L) loaded welds	Load-carrying (✓) or non-load-carrying (x) welds	Fatigue strength, $2S_a$, mean curve value MN/m ² (10 ³ lbf/in ²)	
				at 10 ⁶ cycles	at 10 ⁷ cycles
Plate failures					
P2, double fillet tee [*]	5083-H321	T	✓	77 (11)	–
B, cruciform	5083-F	T	x	74 (11)	–
A, cruciform	5083-F	T	✓	56 (8.1)	33 (4.8)
P2, double fillet tee [†]	5083-H113	T	✓	50 (7.3)	30 (4.4)
F, cover-plate	5083-F	L	✓	29 (4.2)	17 (2.5)
H, channel cover-plate	5083-F	L	✓	–	17 (2.5)
N2, double fillet lap	5083-H113	T	✓	17 (2.5)	–
Weld failures					
C, full width cover-plate	5083-F	T	✓	38 (5.5)	–
D, narrow cover-plate	5083-F	T	✓	29 (4.2)	17 (2.5)
P1, single fillet tee	5083-H321	T	✓	24 (3.5)	15 (2.2)
N1, single fillet lap	5083-H113	T	✓	20 (2.9)	–
P1, single fillet tee	5083-H113	T	✓	14 (2.0)	–

* Oversized welds.

† Undersized welds.

TABLE 5.5 Comparison of Mean Fatigue Strengths from Curves for Joints in 5083-F Alloy at $R = -1$
(from Figure 33)

Presented in order of decreasing strength

Joint classification, type	Transversely (T) or longitudinally (L) loaded welds	Load-carrying (✓) or non-load-carrying (x) welds	Fatigue strength, $2S_a$,* mean curve value MN/m ² (10 ³ lbf/in ²)	
			at 10 ⁶ cycles	at 10 ⁷ cycles
B, cruciform	T	x	88 (13)	51 (7.4)
A, cruciform	T	✓	86 (12)	—
L, fillet attachment	L	x	74 (11)	—
K, fillet attachment	L	x	50 (7.3)	—
J, fillet attachment	L	x	50 (7.3)	—
F, cover-plate	L	✓	39 (5.7)	—
M, fillet attachment	L	x	32 (4.6)	—

* All plate failures.

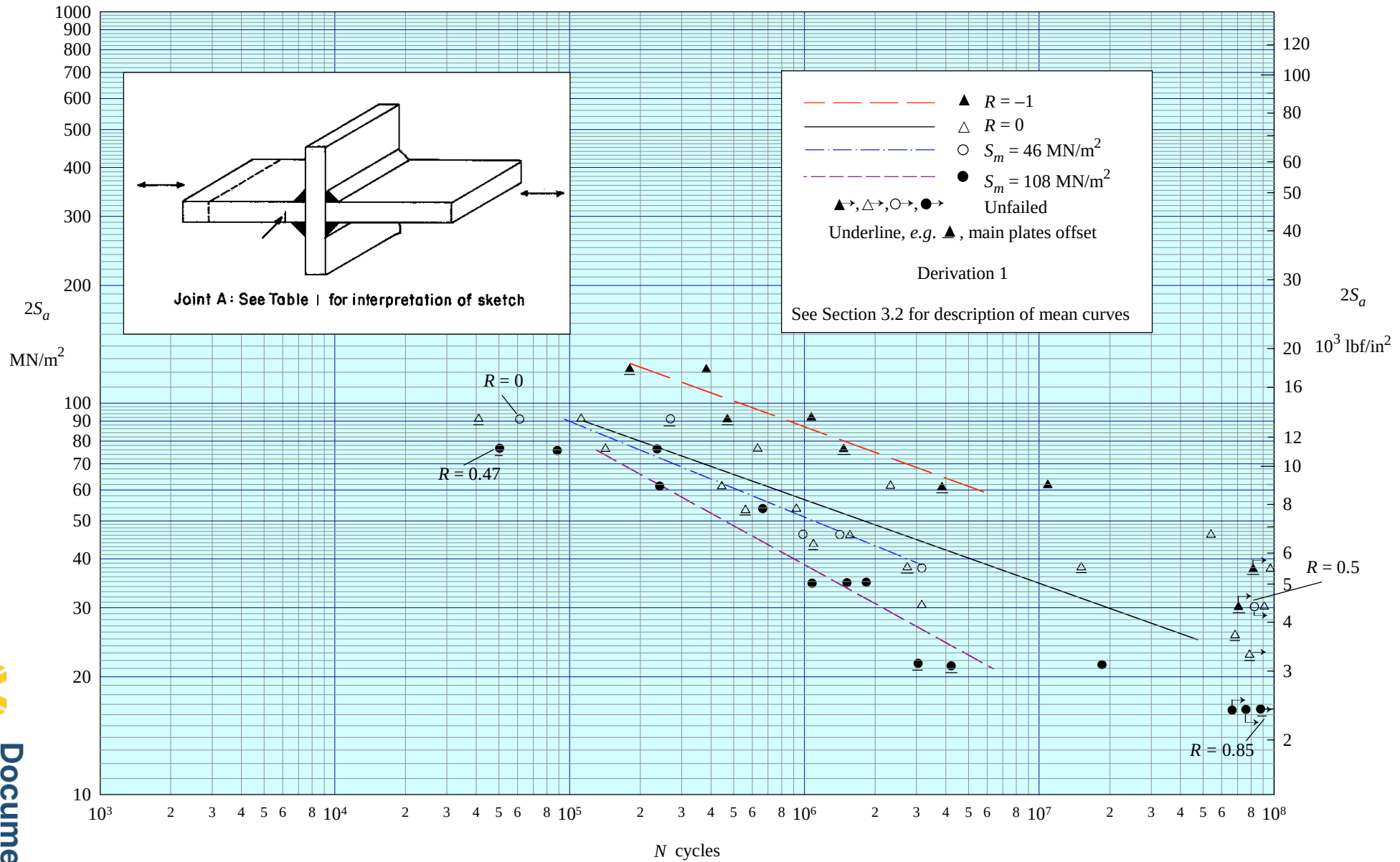


FIGURE 1 FATIGUE STRENGTH OF CRUCIFORM JOINT A, ALLOY 5083-F

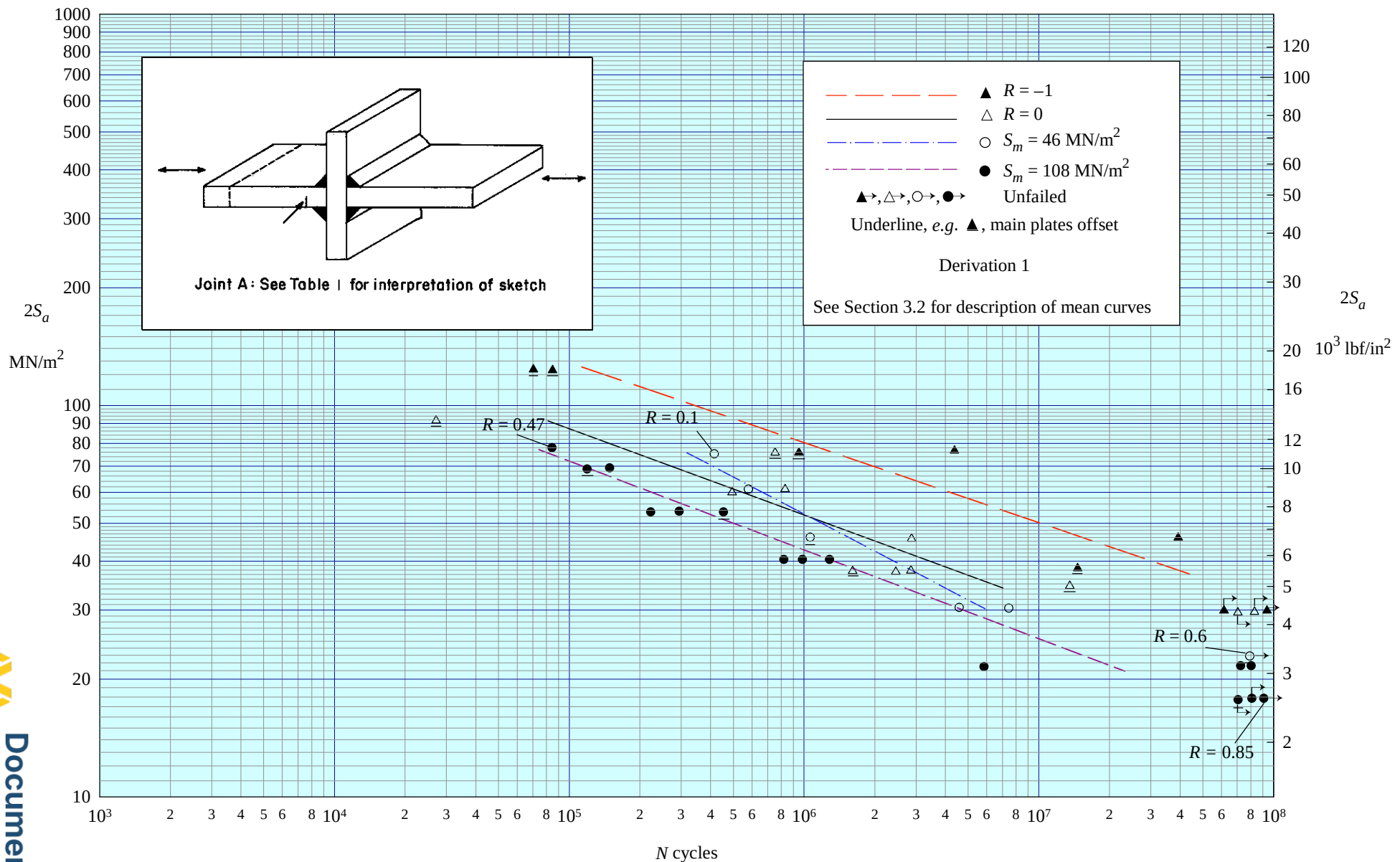


FIGURE 2 FATIGUE STRENGTH OF CRUCIFORM JOINT A, ALLOYS 5251A-H14 AND 5251A-F