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20754

Tweeddale, J. G.  
Lyons, J. V.

Materials (8)  
Iron and Alloys (9)  
Steel alloys, Welded - Heat treated  
(90411.2)

Met. 35

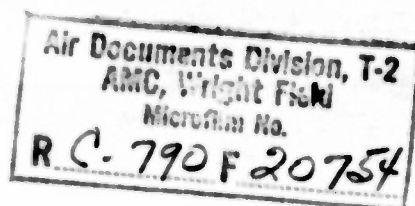
The effect of superficial welding on the tensile strength of chromium-molybdenum steel plate heat treated after welding

Royal Aircraft Establishment, Farnborough, Hants

Gt.Brit. Eng. Restr. Jun'46 8 tables, diags

Tests were conducted to determine the effect of transverse fillet welds on the tensile properties of chromium-molybdenum steel plates. A mild steel electrode was used for the purpose of fixing a lightly stressed attachment. The tests included plate thicknesses and fillet sizes ranging from 1/8 in. to 3/8 in. When the welded specimens were heat-treated to 75 - 80 tons/sq in., there was no reduction in the ultimate tensile strength of the plate and only a slight reduction in the 0.1% and 0.2% proof stresses. Cast analysis of parent material D.T.D. 408, program of tests, and results of check tests are tabulated and the dimensions of welded specimens are illustrated.

*analysis*



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June, 1946

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

The Effect of Superficial Welding on the  
Tensile Strength of Chromium-Molybdenum  
Steel Plate Heat Treated  
after Welding

*Handwritten:* J. G. Tweeddale  
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316541

R.A.E. Ref: M.9163/JGT/171  
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SUMMARY

D Tests have been made to determine the effect on the tensile properties of chromium-molybdenum steel plate (0.25% C, 1.06% Cr, 0.17% Mo.) of making transverse fillet welds on it, using a mild steel electrode, for the purpose of fixing a lightly stressed attachment. The tests included plate thicknesses and fillet sizes ranging from  $\frac{1}{8}$ " to  $\frac{3}{8}$ ". When the welded specimens were heat-treated to 75-80 tons/sq.in. there was no reduction in the ultimate tensile strength of the plate and only a slight reduction in the 0.1 and 0.2% proof stresses. A further report will be issued dealing with tests on plate heat-treated before welding.

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Military Attache, London.

## 1 Introduction

In the past, designers of alloy steel tubular members incorporating welded-on saddle fittings, have been in doubt concerning the strength of the tube in the region of welds. In the absence of information based on suitable tests it has been usual to make conservative estimates, and in instances when the assembly is hardened and tempered after welding it has often been assumed that the strength of the tubular member in the region of a superficial fillet weld was reduced to the same extent as it would be by a butt weld introduced in the tube.

Since it was felt that the strength figures, estimated in this way, would usually be unnecessarily low, it was decided to make an investigation using a chromium-molybdenum steel, to find the actual strength of the material when different sizes of welds were superimposed on its surface.

The material selected for the tests was chromium-molybdenum steel to Specification D.T.D.408 which, of the tubular forms, is the one most commonly used. It was considered desirable to test the material in the two following conditions as regards heat-treatment after welding:-

- (a) hardened and tempered
- (b) no heat-treatment.

This report is concerned only with series (a), that is full heat-treatment after welding, and series (b) will be the subject of a separate report to be issued later.

## 2 Method of Preparation and Test

Plate is the most convenient form of material for tests of the type proposed and therefore it was arranged that a supply of material, of D.T.D.408 chemical composition, should be specially rolled in the form of plate in the three thicknesses 10 S.W.G.,  $\frac{1}{4}$ " and  $\frac{3}{8}$ ". The cast analysis of the material, as given by the manufacturers, is shown in Table I.

To simulate actual conditions it was decided to make the superficial welds between the material under test and superimposed strips of steel to Specification D.T.D.124A, such as might be used in practice to form a fitting or attachment. This material was obtained in the four thicknesses 10 S.W.G.,  $\frac{1}{4}$ ",  $\frac{3}{8}$ " and  $\frac{1}{2}$ ".

Ten combinations of plate thickness and weld size were chosen and included what were considered to be the extreme conditions, of weld size relative to parent material thickness, that might be encountered in practice. These are shown in Table II.

The actual form and size of weld specimen was as shown in Fig.1, so that four standard tensile test pieces, conforming to B.S. Specification No.18 size A, could be obtained from each specimen for test in the direction of rolling of the plate. Welding was performed with the plates firmly held in a welding fixture which prevented buckling during the actual welding. The specimens were allowed to cool down in the fixture before removal. Electrodes, conforming to B.S. Specification 639 Class A, but not of the deep penetration type, were used throughout.

The ten welded specimens and three pieces of chromium-molybdenum plate measuring 8" x 6" x 10G., 8" x 6" x  $\frac{1}{4}$ " and 8" x 6" x  $\frac{3}{8}$ ", for control tests, were hardened by quenching in oil from 880°C. and were then tempered at 450°C. and quenched in oil.

a systematic variation across the width of the original specimen but the effect was small and, since the control test pieces showed a similar variation, this residual effect must have been due to variations in the properties of the plate and not to the welding.

The suppositions, made concerning the cause of the wider variations observed in the first series of tests, were largely correct.

Seven of the welded test pieces fractured away from the weld and the other five fractured at the edge of the weld where the effective area had been slightly reduced by undercutting. The ultimate tensile stresses of the welded test pieces were as high as those of the unwelded controls, but the 0.1 and 0.2% proof stresses were slightly lower.

#### 4. Conclusions

It was concluded that over the range of material thicknesses and weld sizes likely to be encountered in aircraft construction, superficial fillet welds, made with a mild steel electrode, do not reduce the tensile strength of chromium-molybdenum steel of D.T.D.408 composition hardened and tempered after welding. The welds do appear to cause a reduction in the 0.2% proof stress of the material but this reduction appears not to be greater than 3%.

It should be noted that these conclusions apply only to the actual strength of the parent material and take no account of any restraining effect which a fitting or attachment, welded to the parent material, might introduce to cause local stress concentrations in the material.

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#### Attached:

Tables I - III  
Fig.1 = Drg.No. Mat.1947

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#### Circulation:

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D.R.D.T.  
D.R.D.Mat.                   Action copy + 2  
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From the heat-treated specimens, tensile test pieces were cut, four from each of the welded specimens and one from each of the control specimens. The sets of four were numbered consecutively from one side of the plate to the other as shown in Fig. 1.

The test pieces were tested in tension, the values of the ultimate tensile stress, percentage elongation on 2" and position of fracture being recorded; proof stresses were also determined for one central test piece (No. 3) from each set of four and for each of the control test pieces.

### 3 Results of Test

After tabulating the results it was found that there was a marked variation in tensile strength across each set of the welded specimens, the two centre pieces in each set each having a higher strength than the adjacent outer test piece. It seemed very unlikely that variations in welding conditions could have been responsible for this effect since all but two of the 40 test pieces fractured well away from the weld and, as has been described above, they were all heat-treated after welding. It was thought more probable that, owing to the fact that tempering was carried out in a furnace which was not fitted with forced air circulation, the soaking time had been insufficient to ensure that all parts of the specimens reached the furnace temperature.

It was decided to repeat the tests in an abridged form by preparing and testing new welded specimens similar to Nos. 2, 5 and 9 of Table II, taking particular care to obtain uniform tempering conditions. Also, in order to determine whether the properties of the chromium-molybdenum steel plate itself varied across its width, it was decided to heat-treat, along with the welded specimens, 3" x 6" pieces of plate in each of the three thicknesses, 10G,  $\frac{1}{2}$ " and  $\frac{3}{8}$ " and to test four tensile specimens from each of these pieces in the same way as was done for the welded specimens.

The check test was performed in a similar manner to the main test except that, after welding, the specimens were softened by heating at 650°C., and cooling in air, and were hardened and tempered after machining into test pieces. This method was adopted to facilitate machining which had caused some difficulty in the original series of tests.

The specimens were hardened by oil quenching from 880°C. and were tempered at 450° in a forced air circulation furnace, and quenched in oil. They were tested in the same way as before, proof stresses being determined for No. 3 from each set. The results are given in Table III.

If the wartime relaxation of 2 $\frac{1}{2}$ % is taken into account it will be seen that the ultimate tensile stresses and 0.2% proof stresses all came within the range permitted by Specification D.T.D. 408. That some of the ultimate tensile stresses were only just above the relaxed bottom limit of the specified range, is due to the fact that, in choosing the tempering temperature, a diamond pyramid hardness of about 380 was aimed at, which with a conversion factor of 0.21 would be equivalent to a tensile strength of 80 tons/sq. inch. The hardness values actually obtained in tests on sections cut from the corners of control tensile test pieces were 396, 393 and 374 for 10G,  $\frac{1}{2}$ " and  $\frac{3}{8}$ " thick materials respectively. The ultimate tensile stresses obtained were, for the 10G and  $\frac{1}{2}$ " thicknesses, lower than would be expected from these results. This is attributed partly to the fact that the surface layers of the material as received were decarburized and so of lower strength, after heat-treatment, than the core on which the hardness tests were made.

The ultimate tensile stresses of the welded test pieces still showed

TABLE I

Cast Analysis of Parent Material D.T.D.408

Element	C	Si.	Mn.	S.	P.	Cr.	Ni.	Mo
Specified	0.26 Max	0.30 Max	0.8 Max	0.05 Max	0.05 Max	0.8 -1.2	0.5 Max	0.15 -0.25
Actual	0.25	0.25	0.55	0.017	0.035	1.06	0.38	0.17

TABLE II

Programme of Tests

Test No.	Parent Plate Thickness	Super-Imposed Plate Thickness	Gauge of Electrode S.W.G.	Leg Length of Fillet	Remarks
1	10 S.W.G.	10 S.W.G.	10	$\frac{1}{8}$ "	High Current
2	10 S.W.G.	10 S.W.G.	10	$\frac{1}{8}$ "	Low Current
3	10 S.W.G.	$\frac{1}{2}$ "	8	$\frac{5}{32}$ "	Normal Current
4	$\frac{1}{4}$ "	$\frac{1}{2}$ "	8	$\frac{3}{16}$ "	do
5	$\frac{1}{4}$ "	$\frac{1}{2}$ "	6	$\frac{3}{16}$ "	do
6	$\frac{1}{4}$ "	$\frac{3}{8}$ "	6	$\frac{1}{4}$ "	do
7	$\frac{3}{8}$ "	$\frac{1}{4}$ "	8	$\frac{3}{16}$ "	do
8	$\frac{3}{8}$ "	$\frac{1}{4}$ "	6	$\frac{1}{4}$ "	do
9	$\frac{3}{8}$ "	$\frac{3}{8}$ "	4	$\frac{5}{16}$ "	do
10	$\frac{3}{8}$ "	$\frac{1}{2}$ "	4	$\frac{3}{8}$ "	do

TABLE III

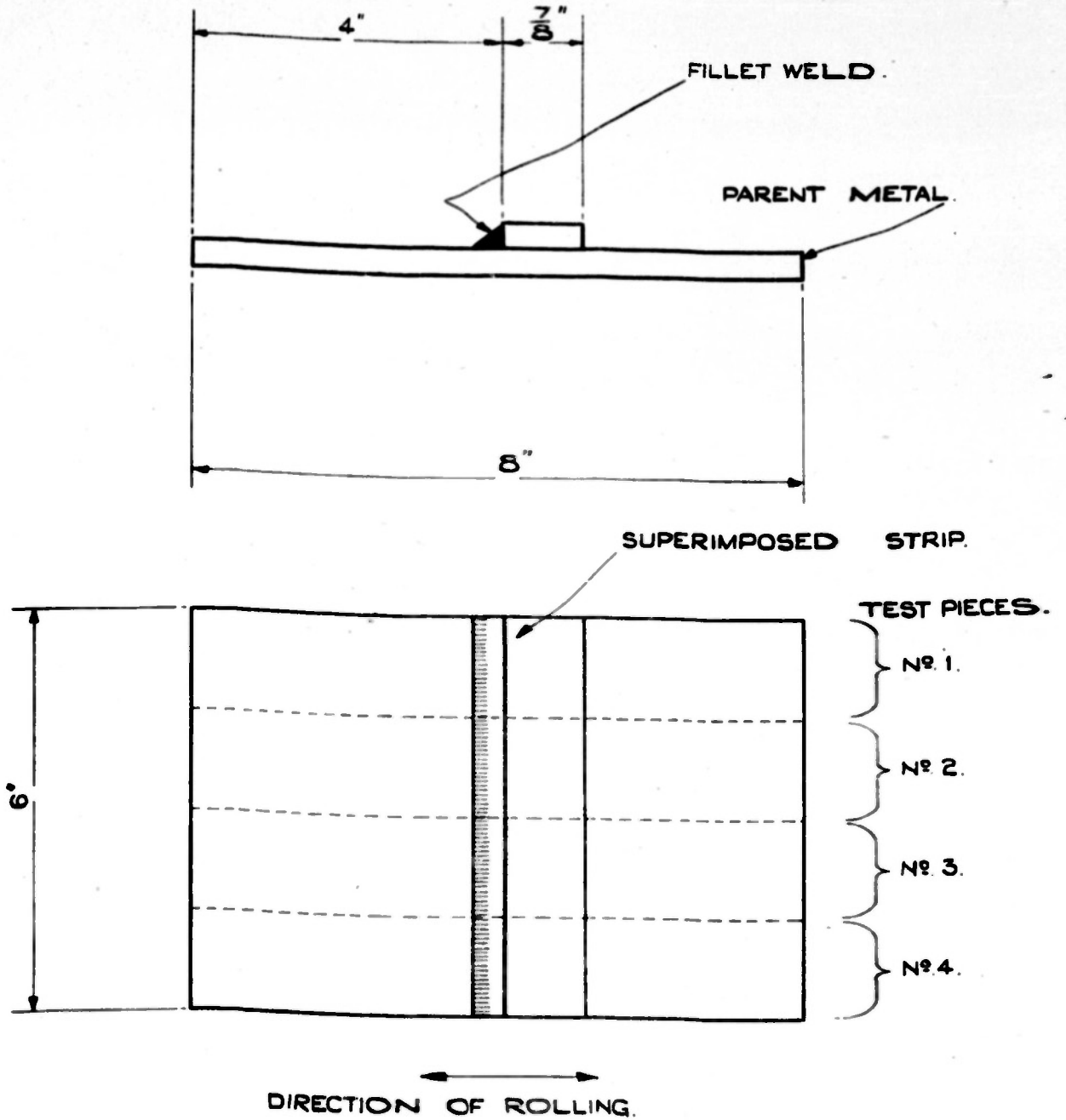
Results of Check Test

Set No.	Parent Metal Thickness	Super-imposed Plate Thickness	Pillet Size	Test Piece No.	0.1% Proof Stress t.s.i.	0.2% Proof Stress t.s.i.	Ultimate Tensile Stress t.s.i.	Elongation % on 2"	Distance of failure from weld ins.
-	10 S.W.G.	Control		1			75.4	7½	-
				2			76.2	8	-
				3	66.8	68.4	75.9	7½	-
				4			75.3	7	-
2	10 S.W.G.	10 S.W.G.	1/8"	1			74.5	7½	3/4"
				2			76.3	6½	5/8"
				3	65.0	67.6	75.9	6½	3/4"
				4			75.7	6	3/4"
-	1/2"	Control		1			74.6	9	-
				2			75.6	2	-
				3	67.4	68.5	73.8	2	-
				4			75.2	6	-
5	1/2"		3/16"	1			76.2	1½	13/16"
				2			77.3	5	3/4"
				3	63.2	66.8	76.8	5	1/16"
				4			76.6	5	0

TABLE III (Continued)

Set No.	Parent Metal Thickness	Support-plate Thickness	Fillet Size	Test Piece No.	0.1% Proof Stress t.s.i.	0.2% Proof Stress t.s.i.	Ultimate Tensile Stress t.s.i.	Elongation % on 2"	Distance of failure from weld ins.
-	$\frac{1}{8}$ "	Control		1			76.9	5	-
				2			77.6	6 $\frac{1}{2}$	-
				3	67.3	70.5	77.5	11	-
				4			76.7	11	-
9	$\frac{3}{8}$ "	$\frac{1}{4}$ "	5/16"	1			76.4	7 $\frac{1}{2}$	0
				2			77.0	7	0
				3	67.0	69.6	78.9	7 $\frac{1}{2}$	0
				4			75.8	5	0

FIG. 1.



DIMENSIONS OF WELDED SPECIMENS.

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Tweeddale, J. G.  
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Gt. Brit.	Eng.		Restr.	Jun '46	8		tbls, diagrs

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