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HOT CRACKING T-JOINT WELDABILITY TEST OF PRECIPITATION HARDENABLE AL ALLOYS

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Abstract: *This article presents research of weldability of aluminium alloys. The research was done at Faculty of Mechanical Engineering, CTU in Prague. In the rolling stock production often used precipitation hardenable Al alloy AlMg1Si1Mn was subjected to the hot cracking weldability test to research its susceptibility to hot cracking during GMAW. Base material and 3 recommended filler wires are subjected to T-joint weld cracking test. As filler wires AlSi5, AlMg4.5MnZr and AlMg5Cr were selected and welding method is GMAW. T-joint weld cracking test is usable test standardized for evaluation of hot cracking, but as the result of this research it was found, that its sensitivity is very low and other weldability test has to be used to asses weldability properly.*
Key words: *weldability test, T-Joint test, aluminium alloy, GMAW*

1. INTRODUCTION

For some Al alloys during welding problem with hot cracking can be encountered (Mathers, 2002). To prevent welding problems and to evaluate influence of base metal and filler wire selection on weldability and hot cracking susceptibility, the hot cracking test should be done. For Al alloys the standardized and recommended hot cracking test for weldments is T-joint weld cracking test according to CSN EN ISO 17641-2. This method is self-restrained fillet weld test. It can be used for MMA, GMAW and GTAW welding. It is not suitable for welding by methods using high current, as is e.g. SAW (EN ISO 17641-1 2004).

In this test only presence or non-presence of cracks is evaluated, so its sensitivity is rather low. This test is one of the weldability tests, according to CSN EN ISO 17641-1, which is also recommended for Al alloys (Hrivnak, 2010).

2. BASE METAL AND FILLER WIRES SELECTION

As base metal precipitation hardenable EN AW 6082 T6 (heat treated) (commercial name „Avial“) was used, because it is often used for rolling stock production. According to CR ISO 15608 it is material group 23.1. Chemical composition is shown at tab. 1 and mechanical properties are shown at tab. 2.

EN AW-6082 [Al Mg1Si1Mn]							
Mg	Si	Mn	Fe	Zn	Cu	Cr	rest
0,6 – 1,2 %	0,7 – 1,3 %	0,4 – 1,0 %	< 0,5 %	< 0,2 %	< 0,1 %	<0,25 %	0,8 %

Tab. 1 - EN AW 6082 T6 - Chemical composition

EN AW-6082 [Al Mg1Si1Mn]							
Tensile strength [MPa]		Yield strength [MPa]		Ductility A_{50} [%]		Hardness [HB]	Young modulus [MPa]
assured	typical	assured	typical	assured	typical	typical	
295	350	240	305	8	11	105	69 000

Tab. 2 - EN AW 6082 T6 - Mechanical properties

Filler wires suitable for GMAW welding of base metal are selected according to recommendations in norm CSN EN 1011-4. Three wires produced by ESAB Vamberk s.r.o., AlSi5 (OK Autrod 4043), AlMg5Cr (OK Autrod 5356) and AlMg4.5MnZr (OK Autrod 5087) were selected. Closer description of filler wires is in norm (EN ISO 17 641-2 2005).

OK Autrod 4043 (AlSi5)				
Si	Mn	Fe	Mg	Al
5.0 %	< 0.05 %	< 0.60 %	< 0.10 %	Rest
OK Autrod 5356 (AlMg5)				
Si	Mn	Fe	Mg	Al
< 0.25 %	< 0.20 %	< 0.40 %	5.0 %	95 %

OK Autrod 5087 (AlMg4,5MnZr)							
Mg	Si	Mn	Zr	Zn	Cu	Cr	Ti
0.6 – 1.2 %	0.7 – 1.3 %	0.4 – 1.0 %	< 0.5 %	< 0.2 %	< 0.1 %	<0.25 %	0.8 %

Tab. 3 – Filler materials - Chemical composition

3. TEST PIECE SHAPE AND DIMENSIONS

According to CSN EN ISO 17641-2, there are 3 possible modifications of test piece (A, B and C). The schematic of the test piece and dimensions are shown at fig. 1 for A modification test piece and at fig. 2 for B, C modification test pieces. Modification A is selected for the test, because the plate thickness 12 mm is often used in the production. Modifications B, C are using very thick plate and/or are difficult to fabricate and should be used for test at more demanding conditions.

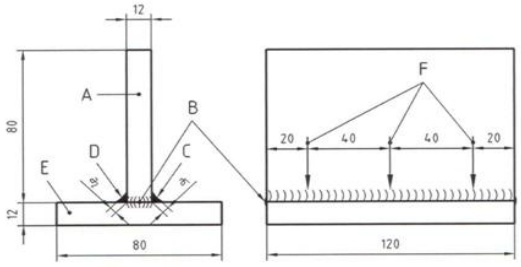

Fig. 1. Used test piece, modification A: test piece shape and dimensions (EN ISO 17641-2 2005)

Modification B is using plate of 40 mm thickness. If this is not available, modification C is using 3 reinforcing plates of thickness 10 mm welded to the horizontal plate. To buy 40 mm thick plate is quite difficult.

4. WELDING PROCEDURE

The test samples were welded by robotic GMAW welding at robotic cell at „Laboratory of education of welding technologies at CTU in Prague“. As shielding gas Ar with purity 4.6 was used (shielding gas I1 according to CSN EN ISO 14175).

Any spacing between horizontal and vertical plates increases hot cracking susceptibility of test weld. From this reason grinding or machining of members` junctions is necessary to reach perfect contact. Welded members need to be clean, without dirt, grease, paint or rust, not to influence weldability test (EN ISO 17641-1 2004).

To assure perpendicularity of the members (90° between horizontal and vertical member) the stitch welds at the members' ends are done – fig. 3. Test welds are done according to CSN EN ISO 15614-2. Welding parameters are selected accordingly to the base and filler material and are listed in tab. 4. Also there are minimum required dimensions of fillet welds according to cited norm. All samples were welded with the identical welding parameters.

Sample	Filler wire	Current [A]	Voltage [V]	Filler feeding rate [m/min]	Welding speed [m/min]
1	AlSi5	280	31.2	17.6	0.5
2	AlMg5Cr				
3	AlMg4.5MnZr				

Tab. 4. Welding parameters

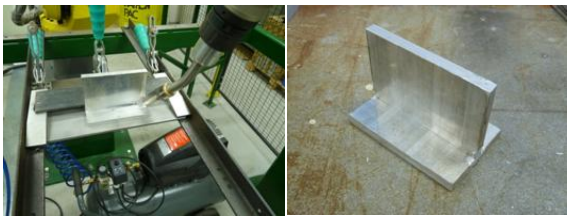

Fig. 2. - Experimental setup and picture of sample with stich welds

To assure stable weld profile the run-on and run-off plates have been used, shown at fig. 4.

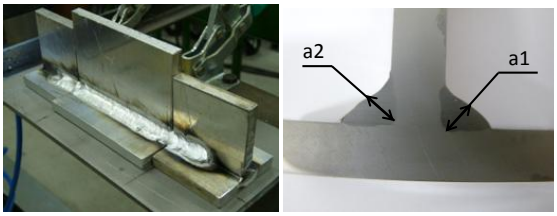

Fig. 3. - Welded sample and cross section of the weld

According to norm CSN EN ISO 17641-2 the T-joint weld test consists of 2 fillet welds a1, a2. The first weld, a1, has to be uninterrupted weld done at PB position with a1> 5 mm. The second weld, a2, has to be started at latest 20 s after a1 is finished. Also the a2 size has to be a2>5 mm. All these conditions have been fulfilled.

5. RESULTS

Welded samples have been cleaned, measured and evaluated for crack occurrence. The size of welds, a1, a2, were measured at 3 positions along the weld and are in tab. 5. To ensure correctness of the test sample according to norm, the size of both opposing welds must be bigger than 5 mm and first weld size, a1, must not be bigger than 120 % of a2. The size of the welds as measured is in accordance with the norm and test results are correct to evaluate hot cracking.

The welds have been subjected to visual test for crack presence. To facilitate visual check also penetration test was done, according to CSN EN 571-1 (in accordance to CSN EN ISO 3452-2,3). The welds according to norm CSN EN ISO 17641-2 are to be: a1 weld completely without cracks, cracks found at weld a2 have to be counted, orientation drawn and length measured.

Filler wire	Weld size a1 [mm]			Weld size a2 [mm]		
	Position 1	Position 2	Position 3	Position 1	Position 2	Position 3
AlSi5	6	6	6	6.6	6.6	6.6
AlMg5	6.6	6.5	6.6	6.6	6.6	6.7
AlMg4,5MnZr	6.2	6.2	6.4	6.2	6	6

Tab. 5.Size of the fillet welds

After complete evaluation of all 3 samples it was found that no cracks were found on any of the 6 fillet welds. As the result of this test, the weldability is good with all used filler wires and no hot cracking occurred.

6. CONCLUSION

The T-joint hot cracking test on 6082 alloy was done by GMAW welding using 3 different filler wires. No cracks have been found on any of the welds, so the base material and filler wires have good weldability according to this weld cracking test (Kolarik, 2011a).

Used T-joint weld cracking test is the recommended standardized test for evaluating hot cracking susceptibility of Al alloys. As our results have shown, the test has very low sensitivity, because all wires passed the test with equal results, because no cracks occurred in any of them. On base of this weldability test no distinction between used filler wires could be done. From these reasons it is difficult to use this test for the complete evaluation of hot cracking susceptibility and the research team proposed continuation of the research by suggesting more sensitive weldability test, e.g. Houldcroft weldability test (Fishbone test) by GMAW, GTAW welding (Kolarik et al, 2011).

7. ACKNOWLEDGEMENTS

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