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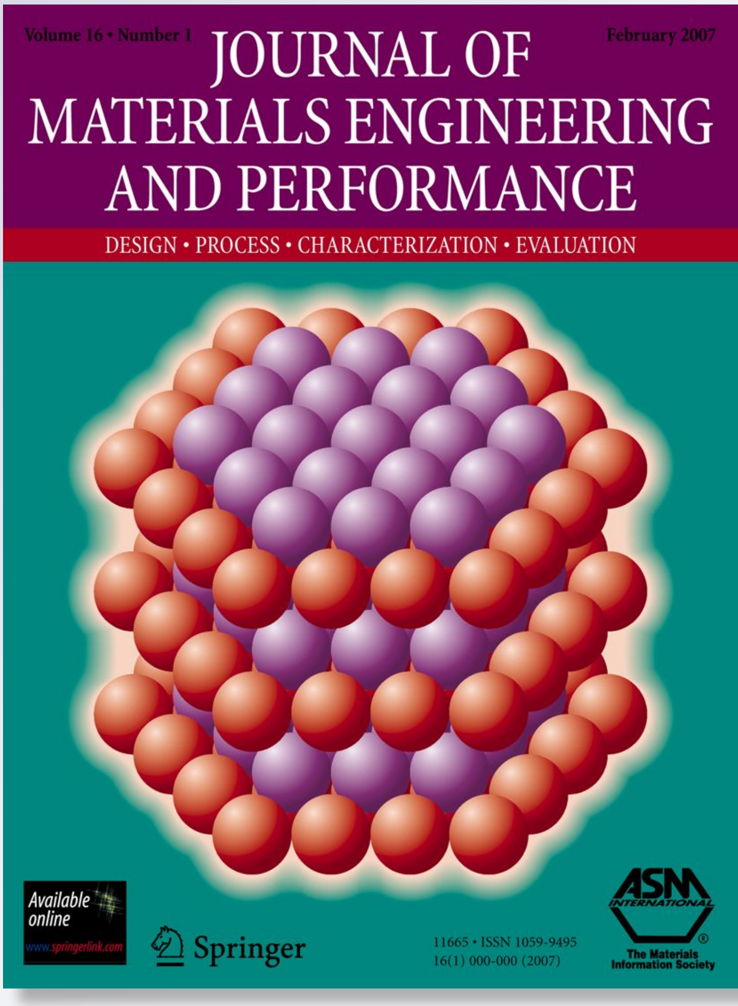
Journal of Materials Engineering and Performance

ISSN 1059-9495

J. of Materi Eng and Perform
DOI 10.1007/s11665-012-0221-4



JMEPEG
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1059-9495/$19.00

Study of the SCC Behavior of 7075 Aluminum Alloy After One-Step Aging at 163 °C

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(Submitted January 26, 2012; in revised form March 20, 2012)

For the past many years, 7075 aluminum alloys have been widely used especially in those applications for which high mechanical performances are required. It is well known that the alloy in the T6 condition is characterized by the highest ultimate and yield strengths, but, at the same time, by poor stress corrosion cracking (SCC) resistance. For this reason, in the aeronautic applications, new heat treatments have been introduced to produce T7X conditions, which are characterized by lower mechanical strength, but very good SCC behavior, when compared with the T6 condition. The aim of this study is to study the tensile properties and the SCC behavior of 7075 thick plates when submitted to a single-step aging by varying the aging times. The tests were carried out according to the standards and the data obtained from the SCC tests were analyzed quantitatively using an image analysis software. The results show that, when compared with the T7X conditions, the single-step aging performed in the laboratory can produce acceptable tensile and SCC properties.

Keywords aluminum, heat treating, non ferrous metals

1. Introduction

7075 aluminium alloy has been used for more than 50 years in aeronautics for the production of critical parts, and only recently it has also been used in mechanical applications, because of its high mechanical strength. The earlier applications in aeronautics and almost all the mechanical applications use the alloy in the T6 condition, which is characterized by the highest ultimate and yield strengths, but, at the same time, especially in the case of heavy sections, by poor stress corrosion cracking (SCC) resistance. For this reason, in new projects in the aeronautic applications, the use of 7075-T6X plates and bars has been forbidden since 1975, and new heat treatments have been introduced to produce T7X conditions. The alloy in the T7X condition is characterized by lower mechanical strength, but very good SCC behavior, when compared with the T6 condition. That is why most of the mechanical designers are considering the possibility of expressly making the T7X condition a requirement, instead of the T6 condition, when using the 7075 alloy. One important difficulty which shall not be neglected in performing this conversion is the poor availability of semi-finished products ex stock in T7X condition in the market, out of the aeronautic circuit.

In the technical literature, the problem of SCC of 7075 aluminium alloy was considered in Ref 1 and widely investigated for many applications. The influence of the heat treatment parameters was demonstrated experimentally in Ref 2-4, and some models theoretically describing the behavior were introduced in Ref 5. All the main results were collected in Ref 6 and 7. According to the technical literature (Ref 6), the SCC behavior of 7075 aluminum alloy can be summarized as reported in Table 1, where the letter describing the corrosion rating refers to the maximum stress which can be applied with no evidence of fracture or cracks.

The Military Handbook 5J (Ref 6) specifies the SCC resistance classes as follows:

A ≥ 75% of the specified minimum yield strength. A very high rating. SCC not anticipated in general applications if the total sustained tensile stress is less than 75% of the minimum specified yield stress for the alloy.

B ≥ 50% of the specified minimum yield strength. A high rating. SCC not anticipated if the total sustained tensile stress is less than 50% of the specified minimum yield stress.

C ≥ 25% of the specified minimum yield stress or 100 MPa, whichever is higher. An intermediate rating. SCC not anticipated if the total sustained tensile stress is less than 25% of the specified minimum yield stress.

D = fails to meet the criterion for the rating C. A low rating. SCC failures have occurred in service or would be anticipated if there is any sustained tensile stress in the designated test direction.

Those authors extensively studied the influence of the heat treatment parameters of 7075 aluminium alloys, starting from the problems of the quench sensitivity of large thickness plates results of which were published in Ref 8 and the influence of the aging parameters on SCC behavior, results of which are collected in Ref 9. One of the main results of the study published in Ref 9 was that a single-step aging to the T73 and T76 tempers could be considered as a good approach for obtaining an acceptable SCC behavior and mechanical properties typical of the above mentioned tempers. That is why the effect of time during a single-step aging at 163 °C was considered to be an interesting topic of investigation, especially

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Published online: 25 April 2012

Table 1 Data from the literature (Ref 6) about SCC behaviour of 7075 from plates, ST direction

Alloy and temper	Corrosion rating
7075-T6	D
7075-T73	A
7075-T76	C

Table 2 Chemical composition of the considered material (wt.%)

Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
0.20	0.30	1.60	0.10	2.50	5.50	0.22	0.10	Bal.

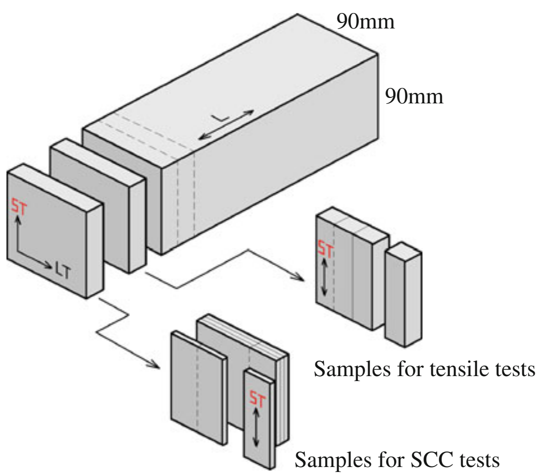

Fig. 1 Tensile and SCC specimens sampling

for the mechanical applications where the two aging steps, typical of T7X, are often thought as a heavy charge in the production management. Starting from the first encouraging results published in Ref 10, the authors extended the investigation on the influence of the time both on the tensile and SCC strengths of 7075 Aluminium alloy after a single-step aging at 163 °C. The samples obtained from SCC tests were analyzed using an image analysis software, their residual strength was tested by tensile tests, and the fracture surfaces were analyzed by a stereomicroscope.

2. Materials and Methods

The nominal chemical composition of the investigated alloy is reported in Table 2. The material was delivered as T651 thick plate (90-mm thickness). The samples for the mechanical and corrosion tests were machined in the ST direction, as reported in Fig. 1.

The tensile and the SCC samples were solutionized at 480 °C for 60 and 30 min, respectively, following the requirements reported in Ref 7; the different aging conditions are reported in Table 3. The choice of the soaking durations of the one-step aging at 163 °C is justified while considering the

Table 3 Investigated aging conditions

Temper	Aging condition
T6	121 °C × 24 h
T73	107 °C × 7 h + 163 °C × 27 h
T76	121 °C × 4 h + 163 °C × 16 h
163_3	163 °C × 3 h
163_5	163 °C × 5 h
163_8	163 °C × 8 h
163_16	163 °C × 16 h
163_24	163 °C × 24 h

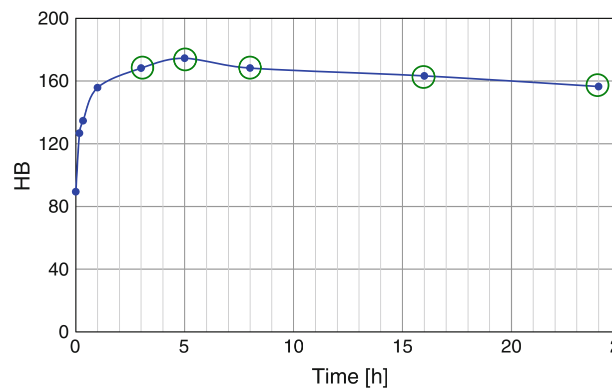

Fig. 2 Hardness values at 163 °C, by varying aging time

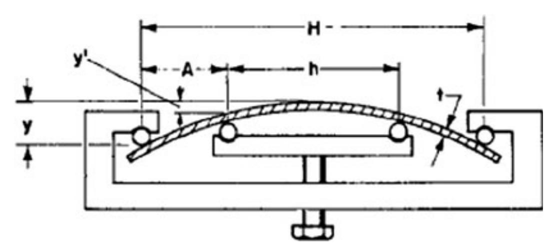

Fig. 3 Four point bending loading of the SCC samples

results of the hardness measurements as reported in Fig. 2, where the selected times correspond to the peak hardness and to the steady-state condition of the curve.

The SCC tests were carried out according to the requirements reported in Ref 11 and 12. The tests were performed in a salt fog chamber at 35 °C for 480 h using a 5% NaCl aqueous solution. The samples were prisms with the following dimensions: 25 mm × 90 mm × 3 mm. Two specimens per aging condition were tested. The samples were tested by four point bending loading (Fig. 3) at a stress level equal to 85% of the measured yield stress. This was found to be a suitable stress level when high corrosion resistance alloys or tempers have to be compared (Ref 1). The tensile specimens had a round section with diameters equal to 8 and 40 mm as useful lengths (Ref 13).

3. Results

The tensile properties are reported in Fig. 4. From the previous data, two main groups can be identified: the former

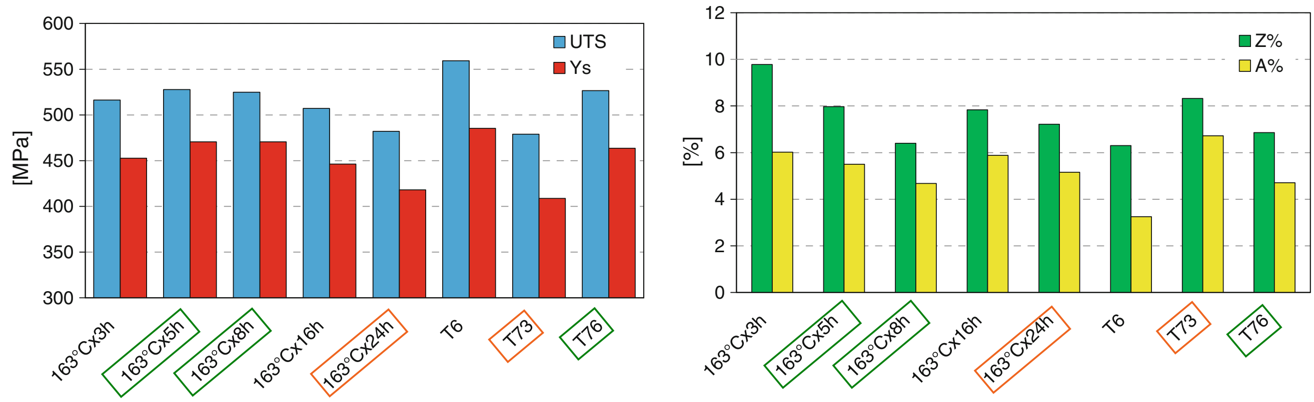

Fig. 4 Average tensile properties for the investigated heat treatment conditions

Table 4 SCC resistance after 480 h in the salt fog chamber

Temper	Outcome	Time to failure, h
T6	Failed	20
T73	Passed	…
T76	Passed	…
163_3	Failed	168
163_5	Failed	260
163_8	Passed	…
163_16	Passed	…
163_24	Passed	…

Fig. 5 Image analysis of a corroded surface

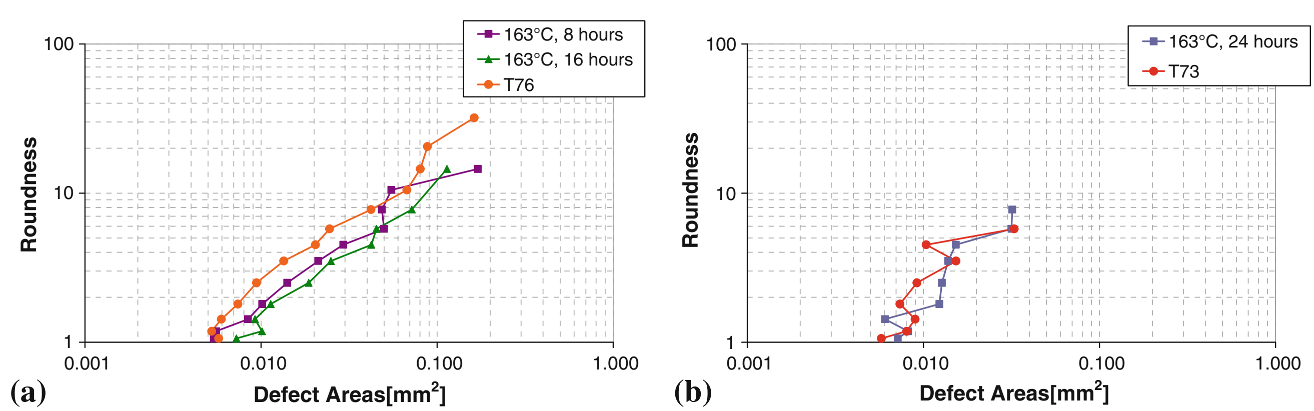

Fig. 6 Roundness vs. defects areas for T76-like agings (a) and for T73-like aging

having the T76 as a reference (T76-like) that includes the 163 °C, 5- and 8-h-aged samples, and the latter having the T73 as a reference (T73-like) that includes the 163 °C, 24-h-aged samples. The results from SCC tests are reported in Table 4.

Aiming to perform a deeper investigation of the SCC samples, the corroded surfaces were observed by a stereomicroscope and the defects were analyzed using an image analysis software. In Fig. 5, an example of the corroded sample at different magnification is reported, and in Fig. 6, the relationship between the roundness (defined as $R = P^2/4\pi A$, where P and A are, respectively, the perimeter and the area of the defect produced by corrosion) and the area of the corrosion defects is presented. It is well known that the roundness of a defect can be related with its notch effect, thus giving a quantitative value of the hazard of the mechanical damage.

The data in Fig. 6(a) show that among the T76-like agings, samples aged at 163 °C, 8 and 16 h, have defects characterized by smaller areas and with a more favorable roundness. In Fig. 6(b), instead, the comparison between T73 and 163 °C, 24-h aged samples, shows very similar results.

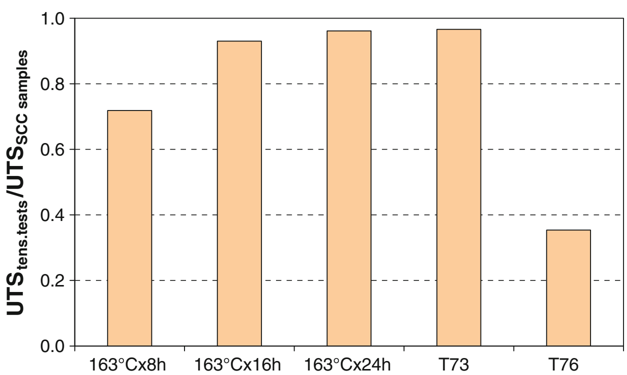

Fig. 7 Ratio between the ultimate tensile stresses obtained from the tensile tests and the ones obtained by tensile loading of the corroded specimens

For a better understanding of the entity of the SCC damage on the unfailed samples, tensile tests were performed on the samples after 480-h exposure in the salt fog chamber.

Figure 7 shows the obtained results, obtained as a ratio between the UTS of as machined samples and UTS of samples after SCC test. The obtained data confirm the T73 aging and the 163 °C, 24 h as being able to guarantee a SCC resistance better than the T76-like agings, while, among the T76-like treatments, 8 and 16 h at 163 °C are confirmed as being able to give higher SCC resistance than T76.

Finally, the fracture surfaces of the corrosion samples after tensile tests were observed by stereomicroscope. Some examples are reported in Figs. 8 and 9.

The observations confirm that T73 and 163 °C, 24-h aged samples show no remarkable defects, whereas on the T76 samples fracture surfaces, deep defects were observed, hence justifying the low value of the ratio reported in Fig. 8.

4. Concluding Remarks

The experimental investigation allowed us to draw the following concluding remarks.

1. The tensile tests resulted in two resistance classes: the T76-like including T76 and 163 °C, 5- and 8-h aged samples and the T73-like including T73 and 163 °C, 24-aged samples.
2. The T6 and 163 °C, 3- and 5-h-aged samples failed the SCC test, whereas the others showed no cracks or fractures within the testing time (480 h).

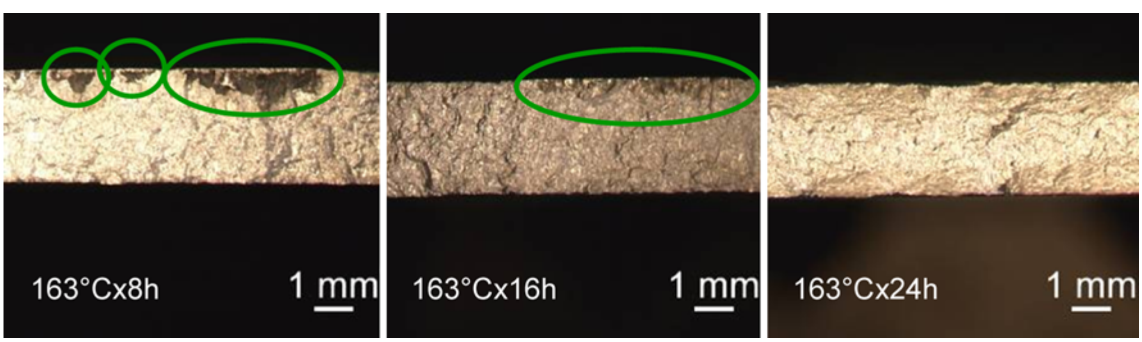

Fig. 8 Defects observed on the fracture surfaces of 163 °C, 8-, 16- and 24-aged samples

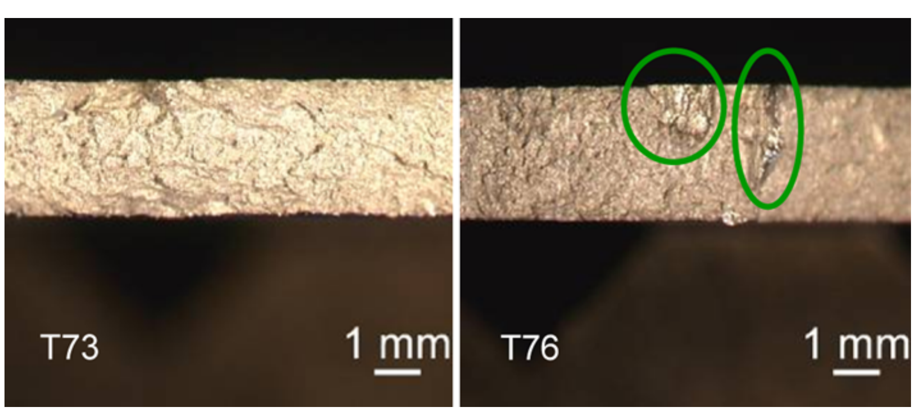

Fig. 9 Defects observed on the fracture surfaces of T73 and T76 samples

3. A further and deeper investigation was carried out on the unfailed corrosion samples using an image analysis software and comparing the ultimate tensile stresses obtained from the tensile tests and the ones obtained by tensile loading of the corroded specimens. The comparison between the tested conditions revealed a weaker corrosion behavior of T76 samples if compared with 163 °C, 8- and 16-h-aged samples, whereas no notable difference was observed between T73 and 163 °C, 24-h-aged samples.
4. Considering both the mechanical properties and the SCC resistance, the T76 temper could be replaced by the 163 °C, 8-h aging, even if a more complete evaluation should be carried out on larger plates submitted to heat treatments in industrial furnaces; moreover, other mechanical tests such as fatigue and fracture toughness should be added to complete the test plan.

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