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Optimisation Of The Scc Behaviour Of 7075 Aluminium Alloy For Aircraft After Two-Step Aging At 225□ F And 325□ F

[1]O.J.Philip, [2]Dr.S.Sathiyamurthy,
[1]*P.G. Student, M.E.(CAD), Sri Ramanujar Engineering College, Chennai-127, (Tamilnadu)*
[2]*Professor, Sri Ramanujar Engineering College, Chennai-127, (Tamilnadu)*

ABSTRACT- 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 Two-step aging performed in the laboratory can produce acceptable tensile and SCC properties.

Keywords- AA7075, Precipitation hardening, SEM, T7X.

I. INTRODUCTION

1.1 ALUMINIUM ALLOY 7075

Aluminum alloy 7075 is an aluminum alloy, with zinc as the primary alloying element. It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable.7075 aluminum alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals. It is produced in many tempers, some of which are 7075-0, 7075-T6, 7075-T651.

Figure 1.1.1 Aluminium alloy 7075

1.2 MECHANICAL PROPERTIES

The mechanical properties of 7075 depend greatly on the temper of the material.[2]

7075-0

Un-heat-treated 7075 (7075-0 temper) has maximum tensile strength no more than 280 MPa (40,000 psi), and maximum yield strength no more than 140 MPa (21,000 psi). The material has an elongation (stretch before ultimate failure) of 9–10%. It is very highly corrosion-resistant and has good strength.

7075-T6

T6 temper 7075 has an ultimate tensile strength of 510–540 MPa (74,000–78,000 psi) and yield strength of at least 430–480 MPa (63,000–69,000 psi). It has a failure elongation of 5–11%.

The T6 temper is usually achieved by homogenizing the cast 7075 at 450 °C for several hours, quenching, and then aging at 120 °C for 24 hours. This yields the peak strength of the 7075 alloy. The strength is derived mainly from finely dispersed eta and eta' precipitates both within grains and along grain boundaries.

7075-T651

T651 temper 7075 has an ultimate tensile strength of 570 MPa (83,000 psi) and yield strength of 500 MPa (73,000 psi). It has a failure elongation of 3–9%. These properties can change depending on the form of material used. Thicker plate may exhibit lower strengths and elongation than the numbers listed above.

7075-T7

T7 temper has an ultimate tensile strength of 505 MPa (73,200 psi) and a yield strength of 435 MPa (63,100 psi). It has a failure elongation of 13%.[5] T7 temper is achieved by overaging (meaning aging past the peak hardness) the material. This is often accomplished by aging at 100–120 °C for several hours and then at 160–180 °C for 24 hours or more. The T7 temper produces a micro-structure of mostly eta precipitates. In contrast to the T6 temper, these eta particles are much larger and prefer growth along the grain boundaries. This reduces the susceptibility to stress corrosion cracking. T7 temper is equivalent to T73 temper.

7075-RRA

The retrogression and reage (RRA) temper is a multistage heat treatment temper. Starting with a sheet in the T6 temper, it involves overaging past peak hardness (T6 temper) to near the T7 temper. A subsequent reaging at 120 °C for 24 hours returns the hardness and strength to or very nearly to T6 temper levels.

RRA treatments can be accomplished with many different procedures. The general guidelines are retrogressing between 180–240 °C for 15 min 10 s.

II. EXPERIMENTAL WORK AND METHADOLOGY

2.1 EXPERIMENTAL PROCEDURE

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.

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 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. 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.

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 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 mm990 mm93 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. The tensile specimens had a round section with diameters equal to 8 and 40 mm as useful lengths (Ref 13).

2.2 ALLOY AT T7X CONDITION

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.

III. RESULTS AND DISCUSSION

3.1 STRESS COROSSION CRACKING TEST

The nominal chemical composition of the investigated alloy is reported in Table 3.1.1. The material was delivered as T6 thick plate (6-mm thickness). The samples for the mechanical and corrosion tests were machined in the ST direction. The tensile and the SCC samples were solutionized at 480^{0}C for 60 and 30 min, respectively, the different aging conditions are reported in Table 3.1.2. The choice of the soaking durations of the two-step aging at 110^{0}C and 165^{0}C was justified while considering the results of the hardness measurements as reported, 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. The tests were performed in a salt fog chamber at 35 ^{0}C for 480 h using a 5% NaCl aqueous solution. The samples were prisms with the following dimensions: 80mmx40mmx6mm. The specimens per aging condition were tested.

Table 3.1.1 Chemical Composition Of Considered Material

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

Table.3.1.2 Aging Condition at 225^{O}F/110^{O}C and 325^{O}F/165^{O}C

SAMPLE	TEMPERATURE	TIME	TEMPER
1	225^{O}F	24H	T6
2	225^{O}F+325^{O}F	8H+16H	T73
3	225^{O}F+325^{O}F	8H+24H	T76
4	325^{O}F	4H	T76
5	325^{O}F	8H	T76
6	325^{O}F	16H	T76
7	325^{O}F	24H	T76

Table 3.1.3.SCC Resistance after 360 hrs.in salt fog chamber

TEMPER	OUTCOME	TIME TO FAILURE
T6	FAILED	30

T73	PASSED	.....
T76	PASSED	.....
T76 (325^{O}F-4H)	FAILED	180
T76 (325^{O}F-8H)	PASSED	.....
T76 (325^{O}F-16H)	PASSED	.....

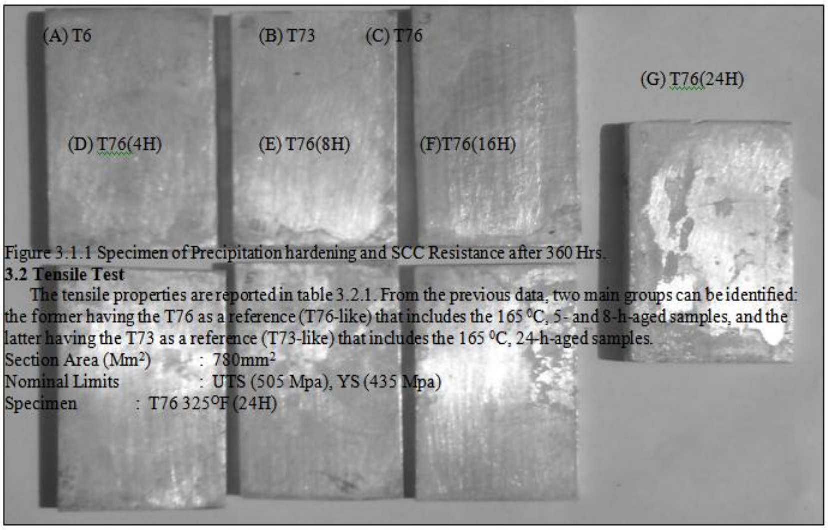


Table 3.2.1 Tensile test

SPECIMEN	ULTIMATE TENSILE STRENGTH (MPa)	YIELD STRENGTH (MPa)	RELATIVE ELONGATION (%A)
T76(24H)	480	420	12

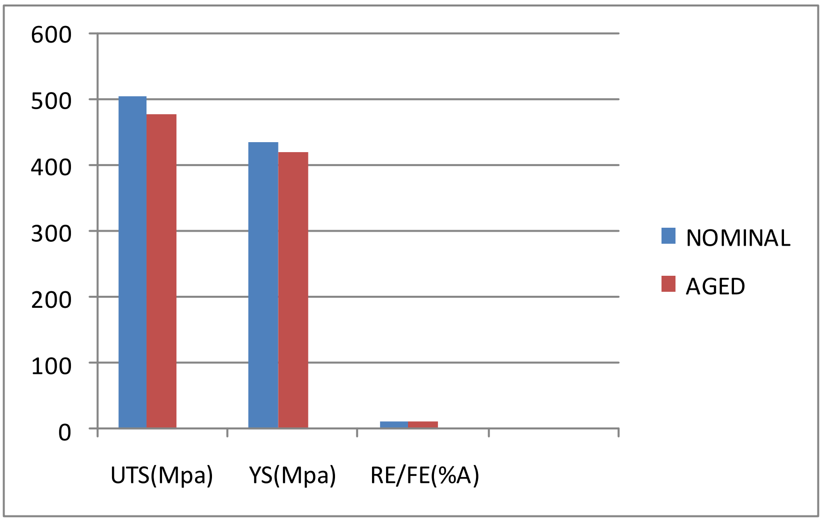


Figure 3.2.1 Tensile test comparison for Nominal And Aged specimen

T76(24H)

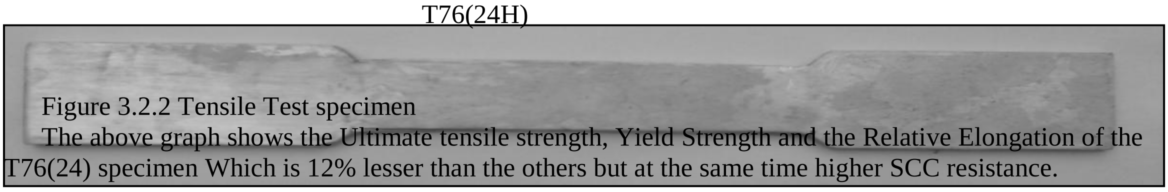


Figure 3.2.2 Tensile Test specimen

The above graph shows the Ultimate tensile strength, Yield Strength and the Relative Elongation of the T76(24) specimen Which is 12% lesser than the others but at the same time higher SCC resistance.

3.3 HARDNESS TEST

The hardness tests were carried out and the results were tabulated. The Figure shows the hardness of various apecimens.

Intender Type : Ball Intender

Affected Load (Kgrf) : 50
Specimen Size : 80x50x6 mm

Table 3.3.1 Hardness Test Results

SPECIMEN	HARDNESS (HRC)
T6	162
T73	158
T76	168
T76(4H)	168
T76(8H)	174
T76(16)	172
T76 (24)	176

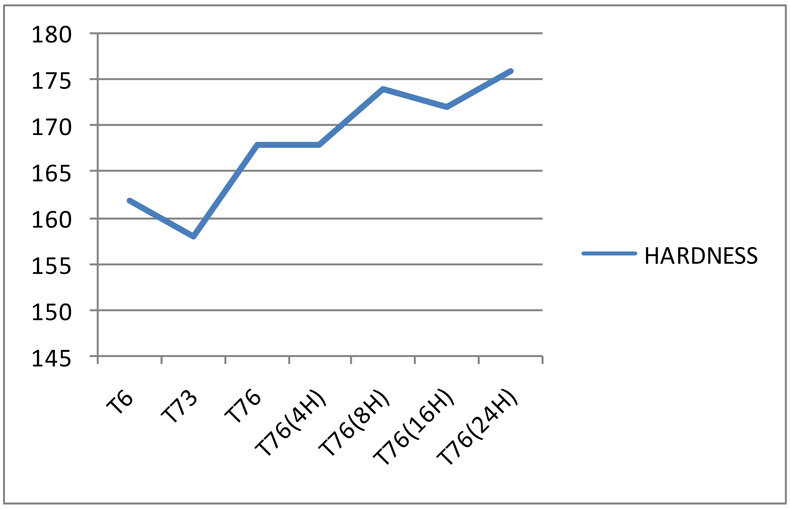
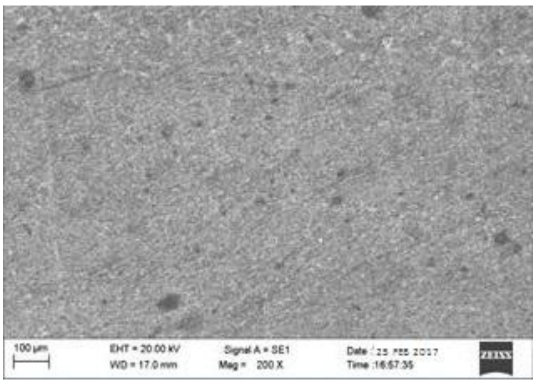


Figure 3.3.1 Graph shows the Hardness comparison

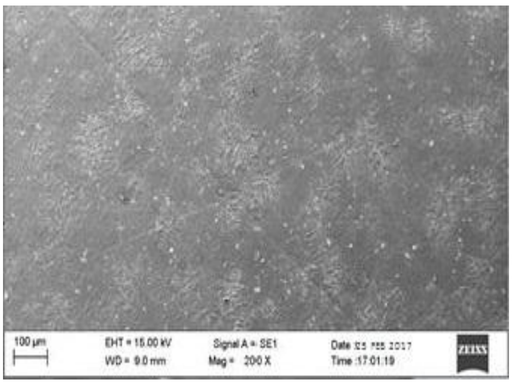
From the above graph shows that the T76(8H) and T76(24h) had the higher hardness than the other aged specimens.

3.4 SCANNING ELECTRON MICROSCOPE ANALYSIS

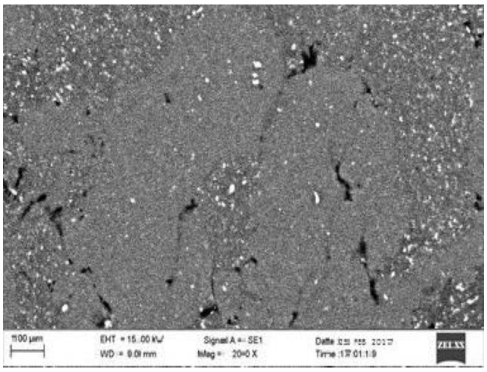
Aiming to perform a deeper investigation of the SCC samples, the corroded surfaces were observed by Scanning Electron Microscope and the defects were analyzed, an example of the corroded sample at different magnification is reported in Fig. 4.4.1.

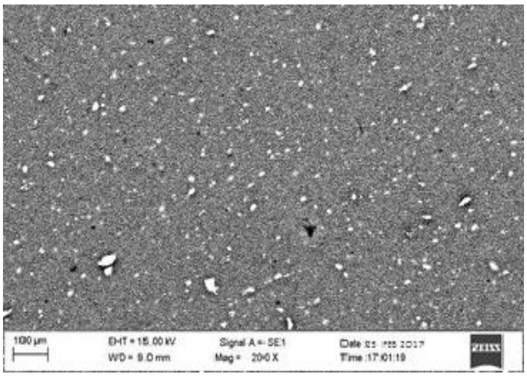


(A) Temper T6

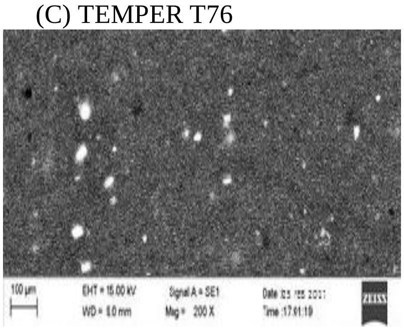


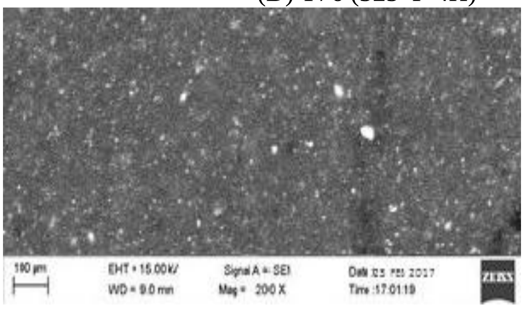
(B) Temper T73



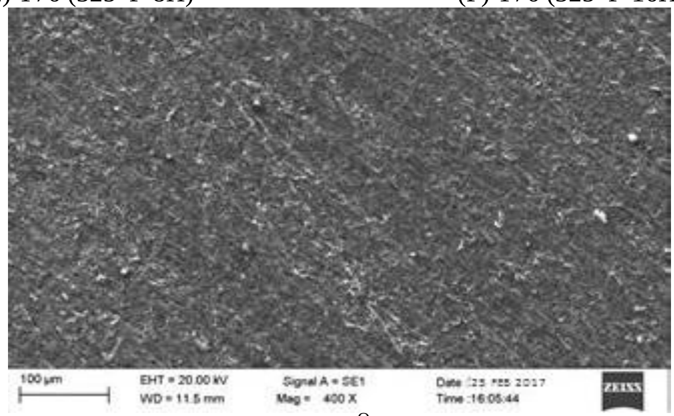


(C) TEMPER T76 (D) T76 (325^{O}F-4H)





(E) T76 (325^{O}F-8H) (F) T76 (325^{O}F-16H)



(G) T76 (325^{O}F-24H)

Figure 3.4.1 SEM images of different tempered specimens

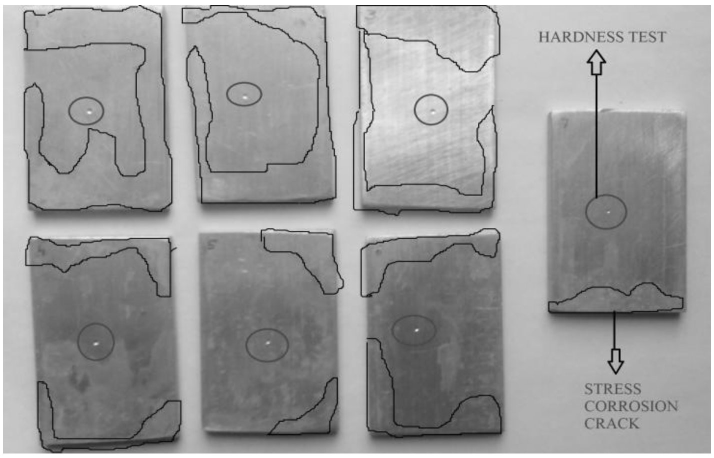


Figure 3.4.2 Images of hardness test and Stress Corrosion Crack

From the above figure, that shows the good corrosion resistance and the lower mechanical strength at two-step precipitating hardening which converts T6 temper into T7X condition.

IV. CONCLUSION

The Stress Corrosion Behaviour Of 7075 Aluminium After Two Step Aging At 225 F And 325F is investigate and study the tensile properties, hardness and the SCC behaviour of AA7075 thick plates when submitted to a two-step aging by varying the aging times. 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 and new heat treatments has been introduced to produce T7X conditions, which are characterized by lower mechanical strength, but good SCC behaviour, when compared with the T6 condition. From that condition T76(8H) and T76(24H) having much lower mechanical strength and very good Stress Corrosion Cracking resistance.

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