Effect of Heat-Treatment on Various Properties of Aluminium 7075: A Review

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***Abstract*: Aluminium is light weight metal and has distinct properties which allows it to use in wide range applications like defense, aerospace and in automotives. The addition of other elements can betterly improves the working properties. Various heat treatments are also the best way to alter its useful properties. Here we are working on Al 7075 alloys, where annealing and precipitation hardening are the dominant heat treatments that are performed in this aluminium alloy While retrogression and reaging useful to deal with stress corrosion cracking behavior of the material. In this review paper we are going to discuss the effect of heat treatment on various properties like tensile strength, hardness, corrosion resistance etc.**

***Index Terms*: Aluminium 7075, heat-treatment, aging, retrogression and re-aging.**

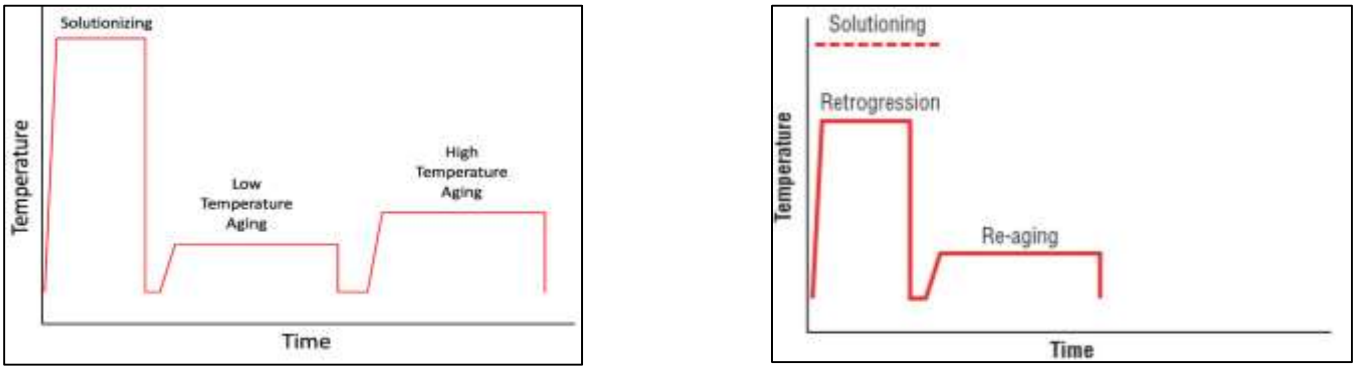
I. INTRODUCTION

Aluminium is chemical element with symbol Al and atomic number 13. It is highly reactive metal & has high strength to weight ratio, hence it is used in foils, kitchen utensils, window frames and in aerospace parts. Aluminium alloys contain zinc, copper, magnesium, silicon, lead and tin which series has designated as 1XXX, 2XXX, 3XXX, 4XXX, 5XXX, 6XXX and 7XXX. Most frequently 7 XXX series are in use because of its versatile properties here we are dealing with 7075 series whose compositions given below.

Al-89% Si-0.40% Fe-0.50% Cu-1.3-2.0% Mn-0.30% Mg-2,1-2.9% Cr-0.2% Ti-0.02% Zn-5.8-6.5%

This series is applicable in the automotive parts and in aerospace industries. Highly stressed parts such as gears, fuse parts, structural components and bows are also comprised of aluminium alloy. The heat treatment which are performed in the 7075 series are solution heat treatment, aging, over aging, duplex aging, retrogression and re-aging. To take advantages of precipitation hardening process, it is imperative to produce a solid solution, the process by which it is accomplished is called solution heat treatment and Care must be taken to not to attain eutectic melting temperature of the material. [1] If eutectic melting occurs as a result of overheating, properties such as tensile strength, ductility and fracture toughness may be disturbed so the temperature range in the solution treatment for aluminium is fixed between 440 to 560 °C for to preserve solid solution formed at the solution heat- treating temperature. [5] The main purpose of solutionizing is to simply put in to solutionize the maximum quantity of alloying elements that are present in particular alloy. [11] The selection of quenching media depends upon to contain solid solution formed at the solutionizing temperature. [7] These quenched samples are then subjected to precipitation hardening (aging treatment) from 120 to 200 °C for 5 to 6 hours and then followed by air cooling or water cooling on room temperature. [17] The material must be straight prior to the aging process because the increase in in strength and mechanical properties drastically reduce the materials ductility making post age straightening difficult. [4] Age hardening treatment can improve yield strength, ultimate tensile strength and hardness value but it curtails the ductility and impact strength of the material. [7] While other method of two step aging treatment includes solutionizing and then quenching the alloys, heating the alloys to a temperature lower than the solutionizing and pre-aging for a given time and finally aging at either the same or at a different temperature from the first aging treatment, this process is named as a double aging. [12]

As per recent research dual aging process can enhance hardness and tensile values and these processes are subjected to commercially on a large variety of non ferrous materials. [12] The aluminium 7075 alloy having a low stress corrosion cracking strength that is attained with overaging but with loss of mechanical strength. [16] Retrogression and re-aging treatments improves the stress corrosion behavior of the alloy while maintaining the mechanical resistance of the T6 temper. [11] The precipitation formed is extremely fine and distributed homogeneously inside the grains, and then it becomes slightly denser and more stable than that resulting from T6 treatment. [3] The retrogression temperature is dominant controlling factor; a higher retrogression temperature can enhance the dissolution degree and promotes the formation of more stable precipitates on raging. [8]



(A) (B)

Figure 1 (A) Double aging (DA) heat-treatment cycle and (B) Retrogression and re-aging (RRA) heat-treatment cycle

In precipitation, strengthened allows extremely small and uniformly dispersed precipitates which act as obstacles to dislocation movement from within the Al matrix upon heat treatment and thus strengthen the materials. [12] This strengthening mechanism is quantitatively measured using hall-petch equation. [2]

II. LITERATURE REVIEW

The effect of annealing and ageing heat treatments on microstructural and mechanical properties of Al 7075 alloy was investigated. The material was casted using green sand mould. During cooling of the cast, cooling rates were also varied. After that annealing and aging heat treatments are follows. The results shows that highest YS and UTS was in as-cast (gradually cooled) samples, The best ductility and impact strength observed in annealed samples but overall good properties observed in age harden samples.[1]

There was clear indication of the micro-segregation of $MgZn_2$ in gradually cooed sample, but not presents in rapidly solidified samples. Also there was tiny and uniform distribution of $MgZn_2$ after aging and coarse particles of $MgZn_2$ after annealing. [1]

The conclusion is that the elimination of micro-segregation can be done rapid solidification and heat treatments. The aging heat treatment gives the best yield strength and ultimate tensile strength with little loss of ductility and impact strength. Opposite behavior can be observed in annealed sample, higher ductility and impact values but poor UTS and YS. [1]

Detailed review was done on strengthening mechanisms and heat treatment of 7XXX Al alloys. Particularly regarding alloy 7075, few summaries can be made [2]

- Ultra fine grains and coarse grain of precipitates have different strengthening mechanism. In UFG Orowan mechanism is dominating factor while the Hall-Petch effect is major contributing factor in CG.
- Cooling rates also affects the mechanical properties. Fast quench interestingly has 37Mpa less Y.S. than slow quench. This is attributed to the existence of Y phase

The alloy Al 7075 was prepared through rheocasting using GISS technique by introducing gas bubbles to the molten alloy at a temperature of 643°C for 7s and holding it for 30s before squeeze-casting with a pressure around 80MPa. The as-cast dimensions were 100 mm × 100 mm × 15 mm. the cast alloy were Solution heat treated 450°C & 480°C for different time period of 1, 4, 8, 12 hr and followed by quenching water at 25°C. after that the aging heat treatment were performed at 120°C, 145°C, 165°C, 185°C for various time. Characterization is done by TEM and tensile test. [3]

The conclusion is made is that very high temperature i.e.480°C Solution heat treatment and prolonged holding period led to formation of deteriorated overheated Mg2Si. The optimum condition for Solution heat treatment is at 450°C for 4 hr. the highest values of combination hardness & UTS is observed in aged 120°C for 72hr. other higher aging temperature leads to decrease in peak values of mechanical properties mainly because of increase in precipitation size. [3]

The study of the effect of the Aging Time on Mechanical Properties and Microstructure of the Al 7075 Alloy was under taken. The experimental alloy was first Solution heat treated at 485°C for 2 hrs and then aged at 120°C for various time periods of 15 hrs, 20 hrs, 25 hrs, 30 hrs and 35 hrs. The SEM analysis showed the presence of $MgZn_2$ precipitates. Also the size of precipitates increases with higher holding times. The tensile and hardness examination shows that best results observed in aged at 120°C for 25hr. the Fractured surface examinations of the alloys showed That the dominant fracture mechanism was the Ductile fracture mechanism. In addition, the planar fracture mechanism was also observed. [4]

Experimental work was conducted to study the consequence of solution treatment on the evolution of the second phases and tensile properties of 7075 Al alloy. The material used for this experiment was casted in laboratory having dimension of 10mm diameter and 110 mm length. The solution heat treatment was done in box type resistance furnace for various temperatures of 450°C, 460°C, 470°C, 480°C, for 4 hrs, 5 hrs, 6 hrs, 7 hrs followed by aging at 120°C for 24 hrs. The results of mechanical testing are as per table 1

Table 1 change in mechanical properties of al 7075 with various heat-treatments [4]

Property	**Ascast**	**450°C, 5 hrs**	**(450°C, 5 hrs) + (120°C, 24 hrs)**	**460 °C, 5 hrs**	**(460°C, 5 hrs) + (120°C, 24 hrs)**	**470°C, 5h**	**(470°C, 5 hrs) + (120°C, 24 hrs)**
Tensile strength MPa	202.41	240.3	310.24	285.2	370.14	235.7	302.55
Elongation %	1.1	1.9	1.5	2.3	1.7	1.8	1.3

The greatest results was attain with solution heat treatment at 460 °C for 5 hrs as the solution treatment temperature and time increase, the coarse black Mg_2Si particles started forming. This can be explained by the fact that the diffusion coefficients of Zn and Cu atoms are larger than the Mg and Si atoms. The fracture surface of the sample of optimum condition reveals predominantly quasi-cleavage rupture [5].

Detailed study to define the mechanical and physical property's correlation of 7075-T6 Al alloy was done. The experimental work aimed for varying the thermal processing parameters and then finds the upshot of that on the properties of Al 7075. The material was taken in sheet form of 3 mm thickness. The variables altered were solution treatment temperatures, quenching media and artificial aging conditions. The samples were exposed to five solution treatment temperatures (420, 450, 480, 510 and 530°C), two quenching media (water and air) and then they were artificially aged. The 10 aging treatments were performed at 121°C (underaged and peak aged) and 165°C (slightly to fully overaged). One treatment was a two-step 107°C/ 8 hrs followed by 163°C/ 24 hrs (overaging). Almost 100 different conditions were defined and studied. The optimum combination of properties was observed in heat treatment cycle which was solution treated at 480°C for 1 hr, quenched in water and then artificially aged at 121°C for 24 hrs. Their conclusion revels the excellent linear relationship between all measured mechanical properties like UTS, YS, and hardness number and the hardness number could be use as predictor to tensile strengths for this alloy [6].

Investigation on the outcomes of pre-aging and aging parameters (time and temperature) on the tensile properties of Al-Mg-Zn (7075) alloys was conducted. The measured amounts of Mg, Zn, Si, Cu, and Fe were added to the molten aluminum to prepare the experimental alloy. The heat treatments performed and results are as per table 2.

Table 2 Change in ultimate tensile strength of al 7075 with various heat-treatments [7]

Condition	Aging Heat treatment Description	UTS (MPa)
As cast	As cast	260
SHT	SHT	370
T4	RT@ 24 hrs	340
T4	RT@ 96 hrs	380
T4	RT@ 192 hrs	390
DA 1	Aging @ RT- 24 hrs + Aging @180°C -8 hrs	370
DA 2	Aging @ 120°C- 24 hrs + Aging @180°C -8 hrs	440
DA 3	Aging @ 65°C- 24 hrs + Aging @130°C -24 hrs	465
DA 4	Aging @ 110°C- 24 hrs + Aging @180°C -8 hrs	410
RRA 1	Aging @ 120°C -29 hrs + Aging @200°C- 10 min.+ Aging @ 120°C -29 hrs	450
RRA2	Aging @ 130°C -24 hrs + Aging @175°C- 3 hrs + Aging @ 130°C -24 hrs	440

SHT – Solution heat-treatment
RT – Room Temperature
DA – Double Aging
RRA – Retrogression and re-aging

The conclusion made is that solution heat treated at 456°C for 8 hrs results in significant improvement in strength compared to as cast sample. Optimum properties were obtained from double aging and RRA. [7]

The influence of novel aging treatments on the tensile properties, inter-granular corrosion, exfoliation corrosion behaviors and microstructures of 7075 Al alloy was studied and compared with the other standard treatments like High temperature pre precipitation (HTPP). The results of that study are as per table 3

Table 3 Change in mechanical properties and inter-granular corrosion resistance of al 7075 with various heat-treatments [8]

Aging state	**Process**			**Tensile strength MPa**	**Yield strength MPa**	**Inter-granular corrosion depth/mm**
	Solution-treatment	***Quenching media***	***Aging treatments parameters***			
T6	470°C for 1 h	Cold water	120°C for 24 hrs	559.8	504.4	0.063 5
T73			160°C for 30 hrs	527.9	464.6	0.043 9
RRA			Aging at 120°C for 24 hrs, retrogression at 203°C for 10 min, and re-aging at 120°C for 24 hrs	568.2	511.8	0.036 1
T6I6			Pre-aging at 130°C for 80 min, interrupted aging at 65°C for 240 hrs, and re-aging at 130°C for 18 hrs	563.0	507.3	0.051 7
HTPP		Cooling to 445°C in resistance oven and maintaining for 30 min for pre-precipitation then quenching in cold water	Aging at 120°C for 24 hrs	538.4	468.5	0.0498

Their conclusion can be summarized as the RRA and T6I6 treatments increase corrosion resistance and also induce strength as comparable to T6. There is significant increase in corrosion resistance with T73 and the HTPP aging treatments, but there is loss of strength too. [8]

The all over material (Al 7075) properties under various heat treatment conditions for an Al–6.0Zn–2.3Mg–1.8Cu–0.1Zr (wt %) alloy was studied. The heat-treatments performed are as per table 4.

Table 4 Heat treatment parameter with different temper designation [9]

Temper designation	**Heat treatment process**	
	Solutinizing treatment	***Aging treatment***
T6	470°C for 1 h + water quench	120 °C for 6 hrs
T74		120 °C for 6 hrs + 160°C for 16 hrs
RRA40		120 °C for 24 hrs + 180 °C for 40 min + 120 °C for 24 hrs
RRA60		120 °C for 24 hrs + 180 °C for 60 min + 120 °C for 24 hrs

The conclusion could be made from the experiments is that the ageing process could significantly improved the tensile strength and hardness but simultaneously lowering the resistance against corrosion. The sequence of various corrosion like inter-granular, exfoliation and stress corrosion was in an order of T74 < RRA60 < RRA40 < T6. The improvements in corrosion resistance were because of fine η precipitates which are discontinuously distributed at the grain boundaries. The RRA process came out as balance treatment which provides improved mechanical properties and the better corrosion resistance. The optimized RRA ageing process was 120°C for 24 hrs + 180°C for 60 min + 120°C for 24 hrs for the experimental Al–Zn–Mg–Cu alloy. [9]

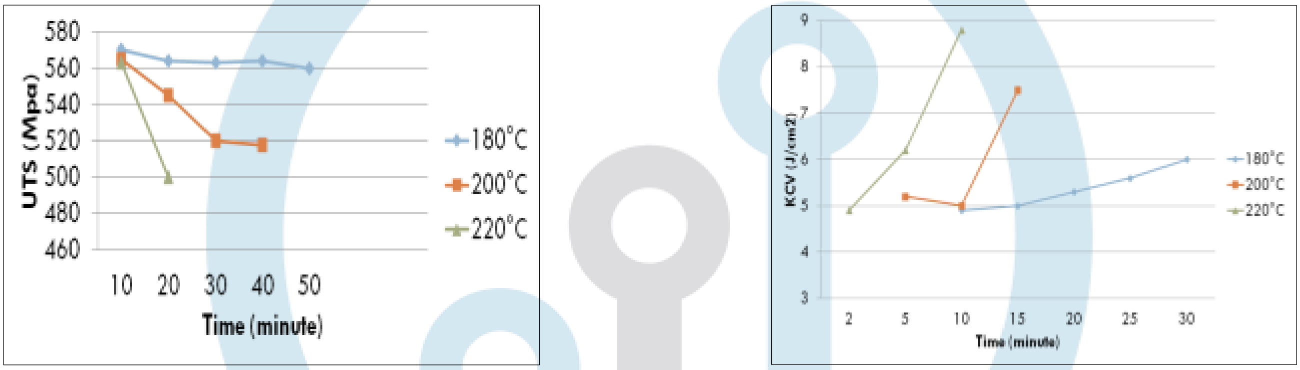
The Strength and Resistance against stress corrosion of Aluminium Alloy 7075-T6 were studied before and after performing retrogression and re-aging Treatments. The material used in this study was extruded aluminium alloy 7075. For the T6 heat treatment the materials were first solutionized at 465°C/ 1 h, water quenched and aged at 120°C/ 24 hrs. The slightly overaged T73 treatment consists of a two-step aging treatment: first, aging at 105°C/ 8 hrs and, finally, aging at 175°C/ 8 hrs. For the RRA treatment, the materials in the T6 temper are retrogressed in the temperature range 180-240 °C for various times and re-aged at 120 °C/ 48 hrs. The variation in strength during the RRA treatments was measured using Rockwell hardness and tensile tests. Double-cantilever-beam specimens were used to measure the stress corrosion crack growth rate as a function of stress intensity. The results show that The T6 structure primarily consists of a fine distribution of Ŋ particles. Initially there was decrease in material strength during the retrogression treatment, mainly because of the dissolution of small Ŋ particles. But during the retrogression treatment grain boundary precipitates coarsened and because of that the volume fraction of precipitates at grain boundary increases significantly. The results show that with increase in the volume fraction of grain boundary precipitates, the crack velocity decreases logarithmically. The RRA treatment gives us a significant decrease in stress corrosion crack velocity without sacrificing its maximum strength. The stress corrosion crack velocity continuously decreases with increase in the time of retrogression and reaches a value which is comparable to the T73 structure at a limiting retrogression time (a critical time) for full recovery of the maximum strength. [10]

The research to study the effect of retrogression treatment time on the properties of alloy al 7075 was conducted. The test pieces were first performed with T6 treatment and then with RRA to various temperatures and holding times as shown in table 5.

Table 5 Holding time and temperature condition for different RRA treatments [11]

Heat treatment	Temperature and time conditions
T6	Solution treatment at 480°C, 90 min + water quenching for 6 sec + aging at 130°C for 12 hrs
T6 + RRA 180 °C	T6 + retrogression treatment at 180 °C for various time of 2 min,5 min, 10 min, 20 min, 30 min, 40 min, 50 min, 60 min, 65 min, 70 min, 75 min and 80 min followed by water quenching than reaged at 130°C for 12 hrs
T6 + RRA 200 °C	T6 + retrogression treatment at 200 °C for various time of 1 min,2 min, 5 min, 8 min, 10 min, 15 min, 20 min, 30 min, 35 min, 40 min, 45 min and 50 min followed by water quenching than reaged at 130°C for 12 hrs
T6 + RRA 220 °C	T6 + retrogression treatment at 220 °C for various time of 30 sec, 1 min, 2 min, 3 min, 4 min, 5 min, 6 min, 7 min, 8 min, 10 min, 15 min and 20 min followed by water quenching than reaged at 130°C for 12 hrs

The effect of various retrogression temperatures and holding time on ultimate tensile strength and impact toughness (KCV) could be understood by graphs shown below.



(A) (B)

Figure 2 Effect of various retrogression temperatures and holding time on (A) ultimate tensile strength and (B) impact toughness (KCV) [11]

The conclusion, that made is that with increase in the retrogression treatment temperature there was downward slop in values of hardness and the rupture strength but toughness value of the notched test pieces increased by the great margin. These results can be explained by dissolution of phases in the matrix during the high temperature (retrogression) treatment hold and by increase in the size of segregations during subsequent aging. The almost similar kind of results was obtain when holding time at constant temperature of the retrogression treatment increases. [11]

The experimental work was conducted on fatigue and corrosion behavior of in service AA7075 aircraft component, which has been served for nearly 40 years, after thermo-mechanical and retrogression and re-aging treatment. AA7075 specimens were taken from a structural component in an F-4 Phantom. Two different treatments were applied to the specimens in addition to as-received T7352 condition. The first treatment was TM treatment including low plasticity burnishing (LPB) as the cold work. In the TM treatment, the specimens were first solutionized at 475°C for 40 min and then followed by water quenched and subsequently undergone artificial aging stage at 120°C for 18 hrs. Next, LPB operation was carried out using a 10 mm diameter ball having a hardness of 65 HRC and then, aging was sustained at 176°C for 2hrs to obtain an increased number of precipitations in the microstructure. In the RRA treatment, the specimens were solutionized at 475°C for 40 min, water quenched and artificially aged at 120°C for 24 hrs. Therefore, the specimens were conditioned as T6. Following the retrogression stage at 195°C for 40 min, the specimens were water quenched. Finally, re-aging stage was conducted as T6 condition. The results of the mechanical testing are in table 6 whereas the results of fatigue crack growth tests are in table 7. The results of electrical conductivity tests and corrosion tests are in table 8.

Table 6 Change in mechanical properties of al 7075 with various heat-treatments [13]

Specimen	Tensile strength (MPa)	Elongation (%)	Hardness (HRB)
T7352	508	16.4	81.5
TM	465	21.6	66
RRA	421	17.1	59.3

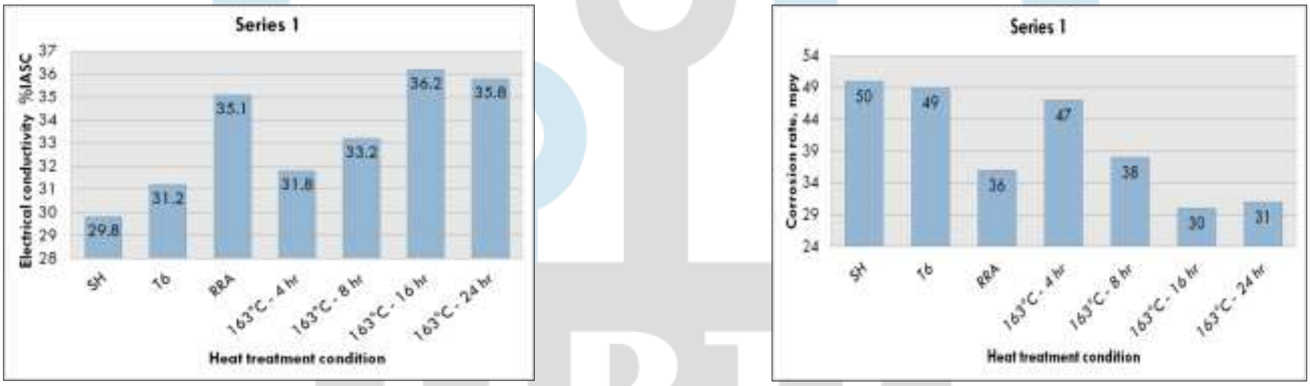
Table 7 Change in fatigue crack growth rate of al 7075 with various heat-treatments [13]

Condition	da/dN (m/cycle)			
	K = 20 MPa√m	K = 30 MPa√m	K = 40 MPa√m	K = 50 MPa√m
T7352	3.086×10^{-7}	6.760×10^{-7}	9.168×10^{-7}	12.495×10^{-7}
TM	1.367×10^{-7}	1.302×10^{-7}	2.589×10^{-7}	4.327×10^{-7}
RRA	2.209×10^{-7}	4.943×10^{-7}	8.782×10^{-7}	9.478×10^{-7}

Table 8 Change in Electrical conductivity (IACS) and Percentage of weight loss (%) of al 7075 with various heat-treatments [13]

Condition	Electrical conductivity (IACS)	Percentage of Weight loss (%)
T7352	41	1.23
TM	35	2.75
RRA	42	1.76

From the outcome of investigation, it was concluded that the fatigue life and corrosion resistance of the specimens with various treatments differ significantly. Although, the hardness and tensile strength results of the material exhibit the identical trends for each treatment. Electrical conductivity is another parameter showing minor changes after the treatments. In short there was significant increase in the fatigue life of AA7075 with TM treatment compared to the RRA treatment. This improvement is substantial for the components used in aircraft. However, corrosion resistance is a major drawback for the TM-treated specimen. [13]
The influence of heat treatments on electrical conductivity and corrosion performance of AA 7075 was studied. The plate with dimension 20mm width, 50 mm length and 6 mm thickness was taken for experimental work. The sequence of heat treatment was as follow, first all samples were solutionized at 460 °C for 1 hr and artificially aged at 120°C for 24 hrs, respectively known as T6 temper. This T6 treatment was followed by retrogression and re-aging (RRA) treatment consisted of heating at 200°C for 2 hrs than re-aged for T6 condition. For duplex aging, after T6, samples were heated at 163°C for 4 hrs, 8 hrs, 16 hrs & 24 hrs. The results are shown in figure 3.



(A) (B)

Figure 3 Effect of various heat-treatments on (A) electrical conductivity %IASC and (B) corrosion rate, mpy [14]

The conclusion of this experiment was as follow, in electrical conductivity there was good amount of hump with almost all treatments with compared to T6, except solutionizing and electrical conductivity which were maximum for duplex aging of 163°C/ 16 hrs. With all the treatments, Corrosion rate decreased with compared to T6 and the minimum corrosion rate was observed with duplex aging of 163°C/ 16 hrs. Duplex aging of 163°C/ 16 hrs for 7075 AA shows better result in electricity conductivity and corrosion resistance. [14]
The tribological features of AA7075 were investigated after the application of retrogression and re-aging treatment. For the experimental work, certified AA7075 Alloy in the T651 temper state were used. The retrogression and re-aging treatment were given as per table 9. The results of testing are as shown in figure 4.

Table 9 holding time, temperature and cooling parameter for different RRA treatments [15]

Starting condition	Retrogression Temperature (°C)	Time (minutes)	Cooling Time(second)	Re-aging
T651	180/ 280/ 370	15/ 30/ 90	1-3	120°C;24 hours

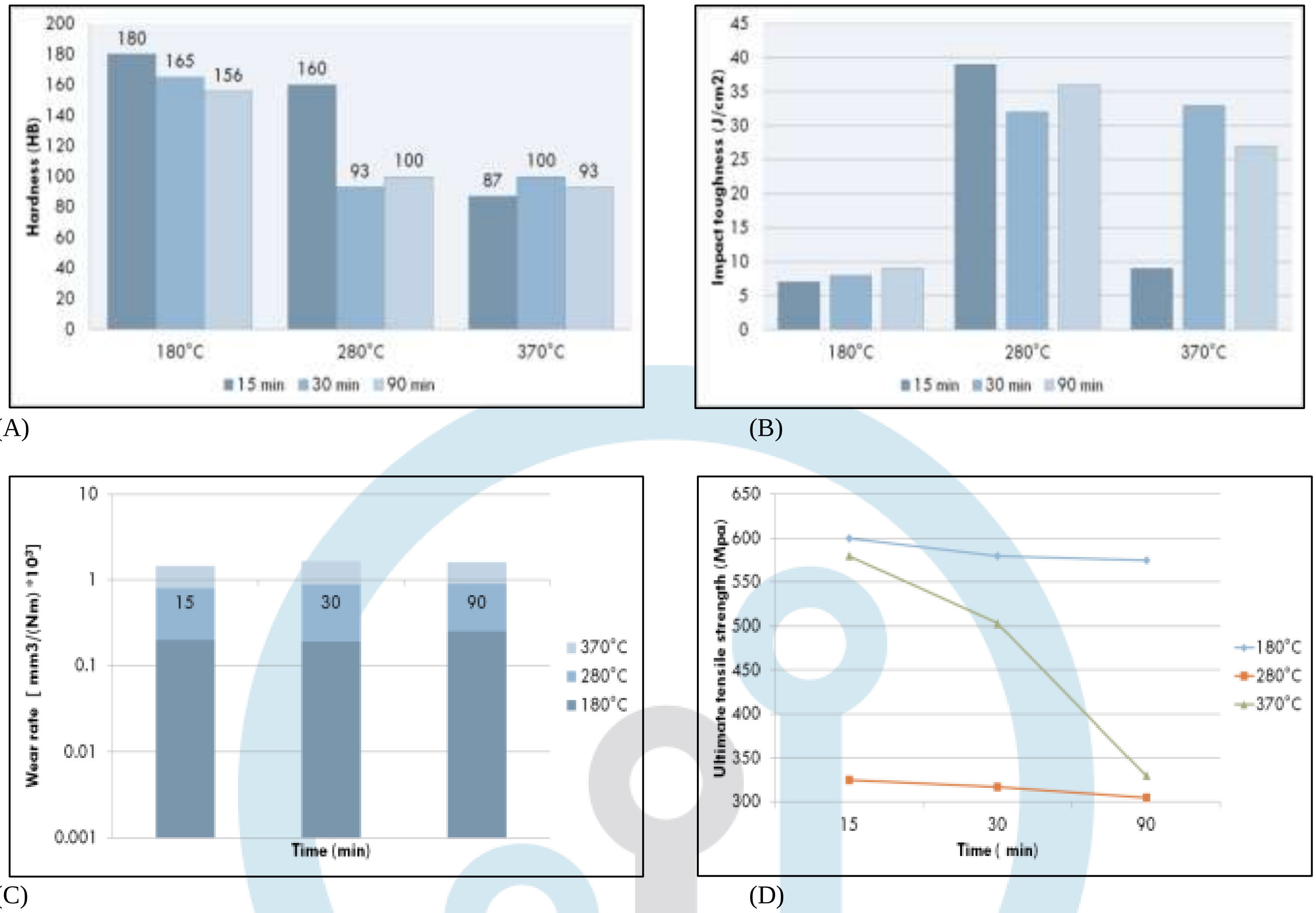


Figure 4 Effect of retrogression treatment on (A) hardness, (B) impact toughness, (C) wear rate and (D) UTS (MPa) [15]

The conclusion is that the hardness and tensile strength values of the alloy decrease with increasing retrogression and re-aging time over relatively low temperatures. In the Case of high temperature and retrogression (370°C; 90 min), it is increased due to matrix solubility. At relatively low temperatures (180°C), the impact strengths are close to the T651 level. It has been determined that the impact resistance increases with the increase of retrogression temperature and duration. The best wear resistance is obtained in the sample treated at 180°C for 15 min due to its high hardness and tensile strength. [15]

III. SUMMARY

- Annealing treatment to Al 7075 can give the higher ductility and impact value but it simultaneously lower the UTS and yield strength.
- Aging heat-treatment (standardize as T6) gives best yield strength, UTS and very good overall mechanical properties. Double aging treatment yet improves the mechanical properties but both this treatment treated sample posses poor corrosion resistance in almost all atmospheric condition.
- To improve the corrosion resistance over aging treatment (standardize as T7) comes in to practice. Over aging can improve corrosion resistance to greater extend but here, drawback is that it lower the mechanical properties to.
- For aero-space application and various other high temperature application where mechanical properties and corrosion resistance both required simultaneously, researchers comes with novel heat-treatment called retrogression and re-aging (RRA), which is capable of developing mechanical properties as comparable to T6 treatment and high corrosion resistance too.
- This RRA treatment is not been standardize at and various parameter is being tested out. Also effect of RRA on other important property like fatigue, wear resistance, electrical conductivity, tribological feature etc. being studying at very high pace.

REFERENCES

[1] Adeyemi dayo isadare, Bolaji aremo, Mosobalaje oyebamiji adeoye, mashood dehide shittu, "Effect of heat treatment on some mechanical properties of 7075 aluminium alloy", 2012

[2] Amir jodeiri feizi, Mehrdad ashjari, "7xxx aluminium alloys; strengthening mechanisms and heat treatment: a review", material science and engineering international journal, PP 52-56, 2018

[3] N. mahathaninwong, T.plookphol, J.wannasin, S.wisutmethanngoon, "T6 heat treatment of rheocasting 7075 Al alloy", material science and engineering, 2011

[4] Ijilal simsek, Dogan simsek, Dursun ozyurek, Suleyman tekeli, "The effect of aging time on microstructure and mechanical properties of the AA7075 alloy after T6 heat treatment", 2019

[5] Xiu-liang ZOU, Hong YAN, Xiao-hui CHEN, "evolution of the second phases and mechanical properties of 7075 Al alloy processed by solution heat treatment", Trans. Nonferrous Met. Soc. China, PP 2146−2155, 2017

[6] R. Clark Jr, B. Coughran, I. Traina, A. Hernandez, T. Scheck, C. Etuk, J. Peters, E.W. Lee, J. Ogren, O.S. Es-Said “study on correlation of mechanical and physical properties of 7075-T6 Al alloy”, Engineering Failure Analysis 12 (2005), PP 520–526

[7] Mahmoud m. tash, s. alkahtani, “Aging and mechanical behavior of Be- treated 7075 aluminium alloys”, international journal of materials and metallurgy engineering, 2014

[8] LI Jin-feng, PENG Zhuo-wei, LI Chao-xing, JIA Zhi-qiang, CHEN Wen-jing and ZHENG Zi-qiao, “Mechanical properties, corrosion behaviors and microstructures of 7075 aluminium alloy with various aging treatments”, Trans. Nonferrous Met. Soc. China, PP 755−762, 2018

[9] Wenchao Yang, Shouxun Ji, QianZhang, Mingpu Wang, “Investigation of mechanical and corrosion properties of an Al–Zn–Mg-Cu alloy under various ageing conditions and interface analysis of η′precipitate”

[10] J. K. PARK, “influence of Retrogression and Reaging Treatments on the Strength and Stress Corrosion Resistance of Aluminium Alloy 7075-T6”, Materials Science and Engineering, A103 (1988),PP 223-231

[11] A. Karaaslan, i. Kaya, h. Atapek, “effect of aging temperature and of retrogression treatment time on the microstructure and mechanical properties of alloy al 7075”, Metal Science and Heat Treatment Vol. 49, PP 443-447, 2007

[12] P.L. Srinivasamurthy, B.N.Sarada, Karthik.B.S, Shamanth.S.Holla “Effect of Retrogression and Reaging Heat Treatment on Microstructure and Corrosion Properties of Al-7075” International Journal of Innovative Research in Science, Engineering and Technology , PP 6436-6441, 2013

[13] Selim Gu ¨rgen ,I ˙smail Sac¸kesen and Melih Cemal Ku¸shan “Fatigue and corrosion behavior of in-service AA7075 aircraft component after thermo-mechanical and retrogression and re-aging treatments” material design and application, PP 1-9, 2018

[14] S. B. Pankade, D. S. Khedekar, C. L. Gogte “influence of heat treatments on electrical conductivity and corrosion performance of AA 7075”, Procedia Manufacturing 20 (2018), PP 53–58

[15] G. Özer, R. Gecu, A. Karaaslan “The effect of retrogression and re-aging treatment on mechanical and tribological features of AA7075 aluminium alloy” Materialwiss. Werkstofftech. 2019, PP 761–768

[16] Itsaree Iewkitthayakorn, Somjai Janudom, Narissara Mahathaninwong, “Solution Heat Treatment of 7075 Aluminum Alloy Affected on Anodic Oxide Layer,” Materials Science Forum, 2016

[17] E. lavernia, G.rai, N.J. Grant, “Rapid solidification processing of 7xxx aluminium alloy : a review”, 1985

[18] C. P. Ferrer, M.G. Koul, B.J. Connolly,and A.L. Moran “Improvements in Strength and Stress Corrosion Cracking Properties in Aluminum Alloy 7075 via Low-Temperature Retrogression and Re-Aging Heat Treatment”.