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The Effect of Heat and Cryogenic Treatment on Wear Properties of 6061 Alloy

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Abstract: The published information on ferrous and nonferrous metals especially Aluminium alloys subjected to deep cryogenic treatment (DCT) have yielded much improved mechanical, tribological and thermal properties resulting in improved properties in the field. Keeping the above aspects in view, tribological studies have been taken up in this work with the main objective of evaluating the wear resistance of the most used Aluminium alloys viz: Al 6061 samples at cryogenic temperature and subjected them to deep cryogenic treatment for temperature . The novelty of the work lies in conducting the wear test in cryogenic atmosphere which is the first of its kind as meagre report is available. It is observed from the wear data that the slide wear resistance and coefficient of friction evaluated in the laboratory conditions show superior wear resistance for the load application of 40N and 50N and lower friction levels for the samples subjected to sliding at cryogenic temperature as well as for the samples deeply cryo treated compared to the untreated ones. The data have been substantiated by Scanning Electron Microscopic features (SEM).

Keywords : AA 6061alloy, heat treatments, wear properties .

I. INTRODUCTION

Aluminium alloy 6061 is one of the most extensively used 6000 series aluminium alloys. It is a versatile heat treatable extruded alloy with medium to high strength capabilities. Aluminium alloys are divided into casting alloys and wrought alloys, and are best suited for different applications. Wrought aluminium alloys, such as the 6061 alloy, are worked by extruding, rolling or forging them into specified shapes. Some alloys can be heat-treated or cold-worked by different methods to increase their strength and hardness, corrosion resistance, ease of fabrication and other advantages. The common grades of commercial 6061 aluminium are 6061-0, 6061-T4, and 6061-T6, however, tempers up to -T9 are produced conditions and good corrosion resistance to sea water. This alloy also offers good finishing characteristics and responds well to anodizing, however, where cosmetic appearance is critical, consider the use of alloy 6063. The most common anodizing methods include clear, clear and color dye, and hard coat. Alloy 6061can be easily welded and joined by various commercial methods. (Caution: direct contact by dissimilar metals can cause galvanic corrosion.) Since 6061 is a heat-treatable alloy, strength in its -T6 condition can be reduced in the weld region. Selection of an appropriate filler alloy will depend on the desired weld characteristics. Consult the Material Safety Data Sheet (MSDS) for proper safety and handling precautions when using alloy 6061. 6061-T6 aluminium is structurally stronger and more useful in the manufacturing of durable products. It is commonly used in aircraft construction. Although primarily used in private rather than commercial aircraft, its strength-to-weight ratio is very high, making it ideal for large parts that need to be very light, such as the plane's fuselage and wings. This light weight also made 6061-T6 aluminum the best choice for the famous gold-anodized plaques that were mounted on board the 1972 Pioneer 10 and 1973 Pioneer 11 spacecraft. Aluminum in its purest form is too soft and reactive to be of structural use. However, its alloys, such as 6061-T6 alloy, make it structurally stronger and more useful in the manufacturing of durable products. 6061-T6 aluminum is commonly used in aircraft construction. Although primarily used in private rather than commercial aircraft, its strength-to-weight ratio is very high, making it ideal for large parts that need to be very light, such as the plane's fuselage and wings. This light weight also made 6061-T6 aluminum the best choice for the famous gold-anodized plaques that were mounted on board the 1972 Pioneer 10 and 1973 Pioneer 11 spacecraft. 6061-T6 aluminum properties make it a material of choice for builders of boats and water-craft because it's strong and lightweight. It is ideal for sailboat masts and for hulls of larger yachts that cannot be made from fiberglass. Small, flat-bottom canoes are almost entirely fabricated from 6061-T6, although the bare aluminum is often coated with protective epoxy to improve its resistance to corrosion.

II. REVIEW CRITERIA

It is observed thatAluminium alloy 6061 (AA 6061) finds various usage as structural material

Adnan N. Abood [1] The investigation of Low Cycle Fatigue (LCF) of aluminum alloy AA6061 in three conditions, annealing (O), T4 and T651. AA6061-O has the higher value of transition fatigue life (NT) because it has the highest ductility.

M. E. Kassner[2], in his study investigate the quench sensitivity of the mechanical properties of 6061 and 6069 aluminum alloys.

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The relationship between mechanical properties and quench delay time at various temperatures between 200–500°C was determined. It was concluded that the 6069-T6 was somewhat more quench sensitive than 6061, increased data on the quench sensitivity of the traditional alloy, 6061-T6

Z. Nikseresht,[3] In his research, the corrosion behaviour and microstructure of Al6061 alloy welded by GTAW (Gas tungsten arc welding) and followed by various heat treatments have been investigated.

improvement of corrosion resistance of AA6061 alloy in seawater. Gravimetric, potentio dynamic polarization, linear polarization resistance and electrochemical impedance measurements were employed

R. Rosliza, W.B. Wan Nik [4]in their studies examine the use of tapioca starch for to study the corrosion behavior of AA6061 alloy in seawater.

Mike Meierin [5] his review paper on 6061-T651 alloy is the most popular 6000 series alloy. It has moderate strength but excellent weld ability compared to other heat treatable alloys, excellent corrosion resistance and a high plane strain fracture toughness. 6061 will age naturally to an essentially stable T4 condition.

A. B. Gurcan T.N. Baker[7] his study investigated the wear resistance of four AA6061 MMCs together with the monolithic AA6061 alloy, all in the T6 condition.

Masoud I. M., [10] In his investigation the effect of aging time and temperatures on the mechanical properties of 6061 Aluminum alloy has been studied. After 4 h solution treatment at 530°C followed by water quenching the 6061 Aluminum specimens were aged at 145, 165,185,

Chee-Fai Tan [11] The work determine the effects of artificial ageing on the strength of 6061-T6 aluminum alloy. The precipitation hardening undergoes a thermal treatment, which consists of heat treatment, quenching process and artificial ageing. The study focused on artificial ageing temperature between 175ºC to 420ºC at different period of time. The study leads to the conclusion that the optimum aged can be achieved within 175ºC to 195ºC at 2 to 6 hours ageing time.

Volker Franco Steier [12] In his work evaluate the effect of a deep cryogenic treatment on the wear behavior and on the microstructure of an aluminum alloy. The wear behavior was investigated using micro abrasive wear tests. The cryogenic treated specimens proved to have similar low wear rates as the specimens coated with CrN. The most distinct improvement was reached with a combination of both techniques .

Nurulhilmi Zaiedah [13] He investigated the effect of heat treatment on mechanical properties and microstructure of 6061 aluminium alloy. The aluminium alloys were examined in the heat treated conditions, using different quenching media, water and oil. The alloy was solution heat treated at temperature of 529ºC for one, three and five hour respectively. Aging treatment was carried out at temperature of 160ºC which is assumed to be the best temperature for ageing process. The results shows hardness and impact strength are inversely proportional to each other, as the hardness of 6061 aluminium alloy decreases and impact strength increases

O. K. Abubakre [14] Specimens of 6061 Aluminum alloy were prepared and quenched in water, sheanut oil and palm oil at temperature of 400^{o}C, 450^{o}C and 530^{o}C to determine the effect of variation in temperature and quenching media on some mechanical properties and the microstructure of the alloy. The results showed that the specimen heat-treated to 530^{o}C and quenched in water has the highest tensile strength of 109 N/mm^2 and yield strength of 70.89 N / mm^2 . The specimen heated at 530^{o}C and quenched in water gave the highest value of 35.50 in hardness (HRC). The toughness property of the alloy, as indicated by Charpy impact values, is better at 530^{o}C for specimen quenched in she-anut oil and least impact strength is observed in specimen quenched in water at 400^{o}C

In the trial contemplates, the AA7075 aluminum compound that is usually utilized in the part of room and aviation inferable from its particular weight, high quality, electrical and warm conductivities was utilized in the test thinks about. Concoction creation of the AA7075 amalgam utilized in the exploratory investigations is given in the Table.

3.0 Chemical composition 6065

Elements	Composition
Si	0.4-0.8
Fe	0.7 Max
Cu	0.15-0.40
Mn	0.15max
Mg	0.8-1.2
Cr	0.04-0.35
Zn	0.25max
Ti	0.15max
Other Elements	0.15total,0.05max Each
Al	Rem

Table 3.1

III. EXPERIMENTAL RESULTS

Fig 3.1

Fig 3.2 Wear Test Specimens ASTM

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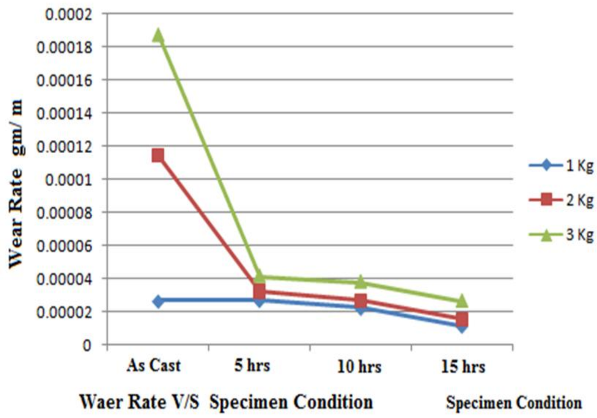
G99-17Microstructure Specimen ASTM E-l2 wear Test

Varying Load in Kg	As cast Soft condition	Cryogenic Treatment at -140 deg		
		5 hrs	10 hrs	15hrs
1	2.644 x10^{-5}	2.685x10^{-5}	2.21x10^{-5}	1.127x10^{-5}
2	1.145 x10^{-4}	3.240x10^{-5}	2.655x10^{-5}	1.543 x 10^{-5}
3	1.876 x 10^{-4}	4.174x10^{-5}	3.826x10^{-5}	2.653 x 10^{-5}

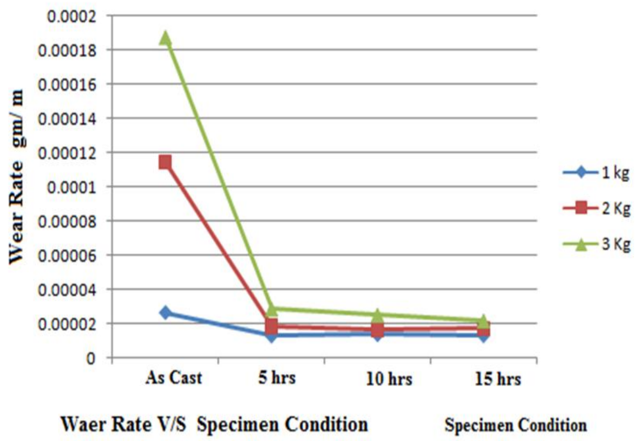
Table 3.1



Graph 3.1

Varying Load in Kg	As cast Soft condition	Cryogenic Treatment at -160 deg		
		5 hrs	10 hrs	15hrs
1	2.644 x10^{-5}	1.281 x 10^{-5}	1.354x10^{-5}	1.299x10^{-5}
2	1.145 x10^{-4}	1.849x10^{-5}	1.637x10^{-5}	1.704x10^{-4}
3	1.876 x 10^{-4}	2.857x10^{-5}	2.517 x10^{-4}	2.174x10^{-4}

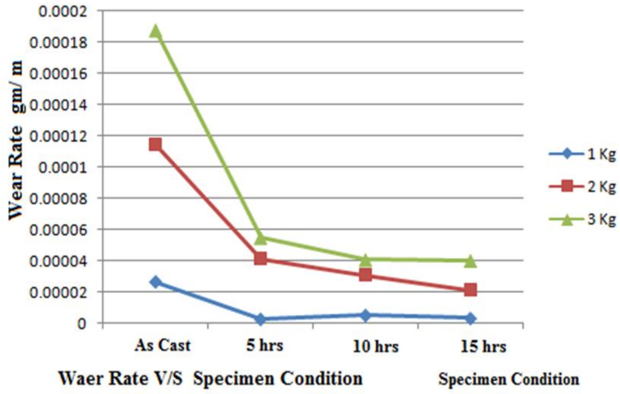
Table 3.2



Graph 3.2

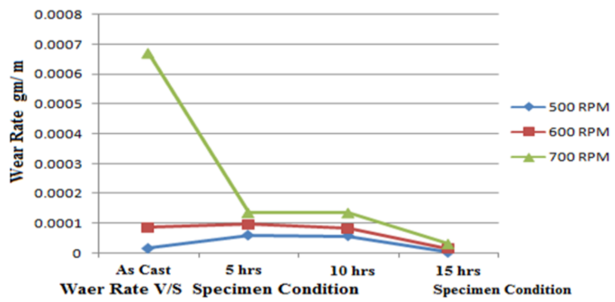
Varying Load in Kg	As cast Soft condition	Cryogenic Treatment at -180 deg		
		5 hrs	10 hrs	15hrs
1	2.644 x10^{-5}	2.858 x 10^{-6}	5.3092x10^{-6}	3.393 x 10^{-6}
2	1.145 x10^{-4}	4.126 x 10^{-6}	3.063 x10^{-5}	2.123 x 10^{-5}
3	1.876 x 10^{-4}	5.452 x10^{-5}	4.042 x 10^{-5}	3.879 x 10^{-5}

Table 3.3



Graph 3.3

Varying Speed RPM	Sliding Distance x10^{-3} m	As cast Soft condition	Cryogenic Treatment at -140 deg		
			5hrs	10 hrs	15 hrs
500	1.021	1.625 x10^{-5}	6.02 x 10^{-5}	5.830x10^{-5}	2.96 x 10^{-6}
600	1.225	8.600 x10^{-5}	9.73 x 10^{-5}	8.23 x 10^{-5}	1.5845 x10^{-5}
700	1.429	6.717 x10^{-4}	1.360x 10^{-4}	1.35 x10^{-4}	3.10 x 10^{-5}



Graph 3.4

Varying Speed RPM	Sliding Distance x10^{-3} m	As cast Soft condition	Cryogenic Treatment at -160 deg		
			5hrs	10 hrs	15 hrs
500	1.021	1.625 x10^{-5}	3.224 x10^{-5}	2.842 x10^{-5}	1.7596 x10^{-6}
600	1.225	8.600 x10^{-5}	4.829 x10^{-5}	3.953x10^{-5}	3.319 x10^{-5}
700	1.429	6.717 x10^{-4}	1.288 x10^{-4}	8.505 x10^{-5}	6.414x10^{-5}

Table 3.4

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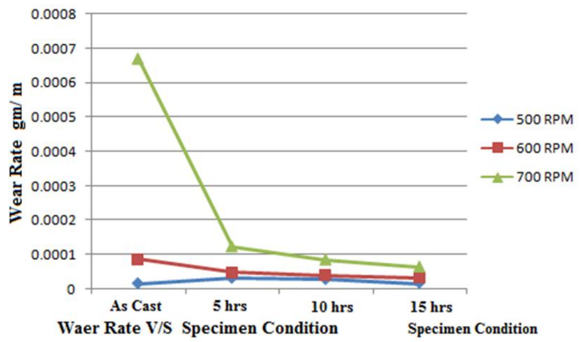
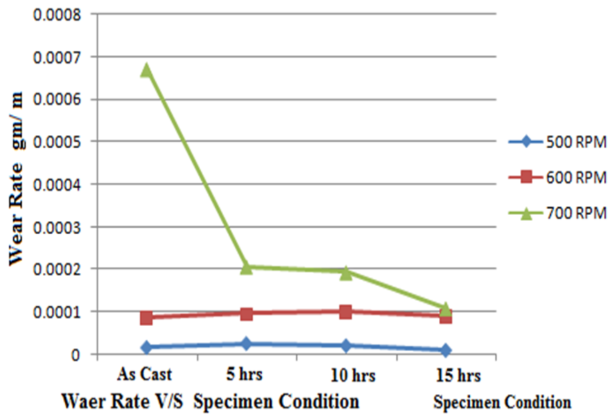


Varying Speed RPM	Sliding Distance $x10^{3}$ m	As cast Soft condition	Cryogenic Treatment at -180 deg		
			5hrs	10 hrs	15 hrs
500	1.021	$1.625 x10^{-5}$	$2.552x10^{-5}$	$2.050x10^{-5}$	$9.597 x10^{-6}$
600	1.225	$8.600 x10^{-5}$	$9.54x10^{-5}$	$1.909 x10^{-4}$	$9.009 x10^{-5}$
700	1.429	$6.717 x10^{-4}$	$2.073 x10^{-5}$	$1.939 x10^{-4}$	$1.0867x10^{-4}$

Table 3.5



Graph 3.5

Microstructure

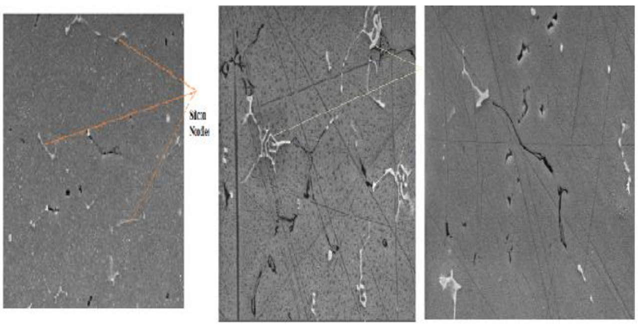


Fig 3.2 1 -140^{0}C 5 hrs 10 hrs 15 hrs

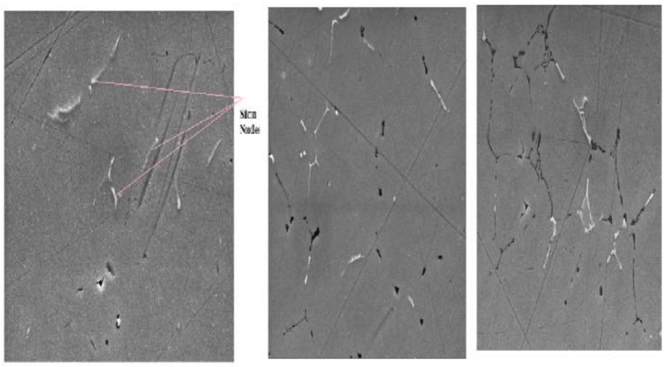


Fig 3. -160^{0}C 5 hrs 10 hrs15 hrs

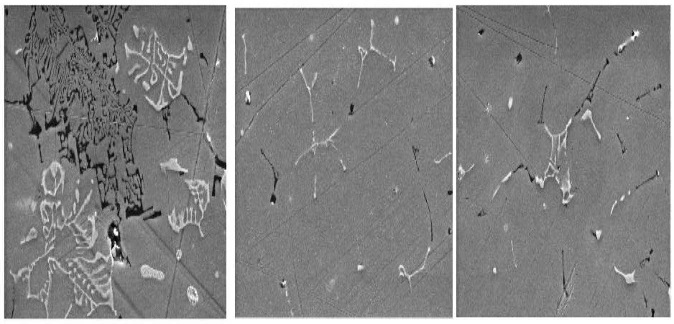


Fig -180^{0}C 5 hrs 10 hrs 15 hrs

1. It is observed that the silicon noodles size decrease this causes for the reason for increasing the hardness of the material.
2. Cryogenic treatment silicon fibers networking are observed in the specimen which is treated at -140^{0}C for 10 hrs.
3. This ha slightly increases the hardness in specimen . Silicon noodles have seen more fibers in 15 hrs treatment specimen.
4. Silicon conditions are observed the specimen treated at -160 ^{0}C for various time periods but silicon networking increases with has increases with temperature.
5. The specimens treated both dendrite and fibrous silicon is observed in specimens treated at -180^{0}C for various time periods the dendrite structures is more in the specimen treated for the 5 hrs and it has decreases with cryogenic treatment increases in cryogenic treatment.
6. The hardness of the specimen with cryogenic treatment has increased for all the conditions but hardness decreased with decrease in cryogenic temperature it is maximum for the specimen treated at -140^{0}C at minimum for the specimen treated at -160^{0}C .
7. The size shape and distribution of the silicon particles could be the reason for the variation in hardness of the specimen. During the principal maturing in the process at 1350C for 24 hours, the 'η' is encouraged inside structure grain. At the point second maturing with high temperature of 1350C are more extended the tie of 22hrs, in 'hastens coarsen in their thickness is diminished an observed in fig.

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The successively contrasted the T6 and T73 treatments brings down the quality of al7075[6].

In the interim few of coarse particles are watched. In investigation demonstrates the coarse particles are contain the alloy components as observed .in lower thickness of an 'η' hasten and the arrangement particles can be clarified by pre-precipitation process.

IV. CONCLUSION

Microstructure of a cast example comprises istage iof ieutectic i+ iα-Al, ithe ilattice iand ieutectic istage iavailable iwith iin igrain ilimits. iThe iage iand isolutionzed isolidified ithe istructure icomprise iof iaccelerates isame idisseminated inext istage icomponents iin iAl inetwork. In inetwork iit irequired ire-precipitation iof ithe inetwork ihappens iduring icryogenic itreatment iand iit ican ibe icoarsened ithe igrain ilimit iaccelerates. iOur istudy iencourages ito idevelop ia iprogressively istable igrain ilimit ihastens, iin ithis imanner iimproves i'η1'stage iwith ire-precipitation. iWith icryogenic itreatment isamples iare iappeared irelative iconsumption iobstruction ithan ithe ispecimen. iThe iage iand isolutionzed isolidified imicrostructure icomprise of accelerates same iconveyed to next stage icomponents iin iAl inetwork.

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