Influence of Aging on Hardness and Tool Wear of Artificially Aged Aluminium Alloy 6061

Surinder Pal[1], Akhil Khajuria[2, *], Modassir Akhtar[3]

[1]Research Scholar, Department of Industrial and Production Engineering, NIT Jalandhar, India

[2]Research Scholar, Department of Mechanical Engineering, NIT Jalandhar, India

[3]Senior research fellow, Materials Testing Division, CSIR-NML, Jamshedpur, India

Abstract - Aluminium alloy 6061 (AA6061) has been used in a variety of engineering applications owing to better attributes like good workability, brazability, corrosion resistance and toughness. Such high demand has produced thrust among researchers to explore the potential of this alloy. AA6061 is given different heat treatments as desired by a particular engineering application before it can be put into machining. However, heat treatment of AA6061 increases hardness of the alloy, which further increase tool wear during machining. As such, current investigation has focused on machinability of AA6061 and its effect on tool wear on a set of diverse heat-treated aging conditions. i.e. non- heat treated, solution heat treated and aged (SHTA) by single point turning method. The samples were first solution treated and then aged at 180ºC for 1, 6, 12 and 24 hours respectively. After SHT and aging, micro hardness of all work pieces was measured. The machining of work pieces was carried out at various cutting speeds by CNC turning centre while keeping feed rate and depth of cut as constant. Results from present investigation revealed that aging time significantly affects hardness values of different heat-treated aluminum alloy 6061 specimens. It was also found that tool wear and hardness values are noticeably affected by cutting speeds and different aging times.

Keywords - Aluminium alloy 6061; artificial aging; Hardness; Turning; Tool wear.

I. INTRODUCTION

An alloy is a material made out of two or more metals or a metal and a non-metal. There has been an impressive interest from industries for these combinations in light of the fact that 66% of every extruded item is made of aluminium and 90% of those are produced using 6XXX arrangement alloys [1-3]. In 6XXX series, 6061 aluminium alloy (AA) is most widely used alloys for typical applications like aircraft structures, aluminium cans, automotive parts etc. AA6061 is a precipitate hardened alloy, and contains magnesium and silicon as its major micro-alloying elements [4]. The alloy has improved mechanical properties with better weld ability and machinability [5-6]. The 6061 aluminium combinations has been employed as a part of automotive business for the manufacture of few sorts of vehicles parts for example wheel spacers, boards and even in the car chassis structure. The main heat treatment processes involved for AA6061 are solution heat treatment and artificial aging. The solution heat treatment is given at a temperature between 460°C and 530°C with all the micro-alloying elements being present in aluminium solution. The purpose of giving this heat treatment to this alloy is to impart sufficient strength, which increases with the precipitation by holding it a high temperature for considerable time. However, solution heat treatment also takes away the ductility of the metal. The second heat treatment is given at a little low temperature less than 200°C and is referred as artificial aging [7]. With the variation in solution heat treatments to AA6061 mechanical properties are altered simultaneously which further lead to different machinability properties. The current investigation lays focus on the effect of different aging times at 180°C on the hardness and tool wear when turning AA6061 aluminium alloy work pieces under control, solution heat treated (SHT), solution heat treated and aged (SHTA) conditions. The objective of current investigation is to analyse the effect of aging on hardness and tool wear of artificially aged AA6061. Also hardness and flank wear of the tool for as received, solution heat treated and solution heat treated then aged conditions have been investigated.

II. EXPERIMENTATION

A. Materials and methods

AA6061 was received in the form of six cylindrical rods having equal length and diameter of 200 mm and 50 mm respectively as shown in Figure 1. These rods were heat treated to produce precipitation to various degrees. The T6 heat treatment to aluminium alloys involves solution heat treatment and subsequent artificial aging and quenching which is a common method to increase the strength aluminium alloys [8]. For carrying out solution heat treatment and aging, muffle furnace TEMPO TI-58HTB model was used. The material was kept at a temperature of 100ºC for 1 hour, which is called as soaking time. This ensures a homogenized solid solution is produced before continuing a high temperature heat treatment process of the aluminium alloy. Five samples were solution heat treated in the muffle furnace at 530ºC temperature. Aging also known as precipitation hardening is a process of putting the samples above room temperature but below the solvus temperature to produce uniformly and finely dispersed precipitates. Mechanical properties of the material start degrading after a particular time of aging.

Figure 1 Cylindrical rods of AA6061

Table 1 AA6061 samples with designations

Designation	Condition
A	Non-heat treated
B	Solution heat treated
C	Solution heat treated then aged for 1hour
D	Solution heat treated then aged for 6 hour
E	Solution heat treated then aged for 12 hour
F	Solution heat treated then aged for 24 hour

The machining of these alloys was done on CNC turning Centre. Hardness was measured on a micro hardness tester (VMHT Leica) whereas for tool flank wear, optical microscope was used. In solution heat treatment process all the soluble hardening element of the alloy are in single solution or in a single phase α only and are assumed to be homogenized. The aim of this step in heat treatment process is to preserve the single phase solid solution formed during SHT process by rapidly cooling it near about room temperature. Cutting tool of make titanium nitrate coated carbide of diamond paste (CNMG120408-M3) was used for turning of AA6061.

Machining of as received condition, solution heat treated and SHTA work pieces were carried out on BATLIBOI CL-2050 CNC turning Centre at Central Institute of Hand Tools, Jalandhar. Variable used for this work are feed, depth of cut and spindle speed. Out of these feed and depth of cut were kept constant with values 0.1mm/rev. and 1 mm respectively.

Spindle speed was varied at five levels of 100, 150, 200, 250 and 300 meter/minute and for every speed 80mm of cut was taken. Aging time and cutting speed have been considered as variables in this work. General factorial design has been utilized to design the experiments. A total of 30 experiments were performed.

B. Measurements

At the onset, 20 mm pieces were cut from all six work pieces and then all were grinded till appropriate finishing was achieved. Then hardness was taken with the help of micro hardness tester by applying 300gms load and a dwell time of 10 seconds. For each work piece two hardness readings were taken and an average of these two is reported.

III. RESULTS AND DISCUSSION

A. Influence of aging time on hardness

Hardness values obtained for SHT and SHTA conditions are plotted in Figure 2 which helps to understand the effects of solution heat treatment and aging time on hardness of AA6061. A positive slope in plot with increasing time shows that hardness increases with increased aging time.

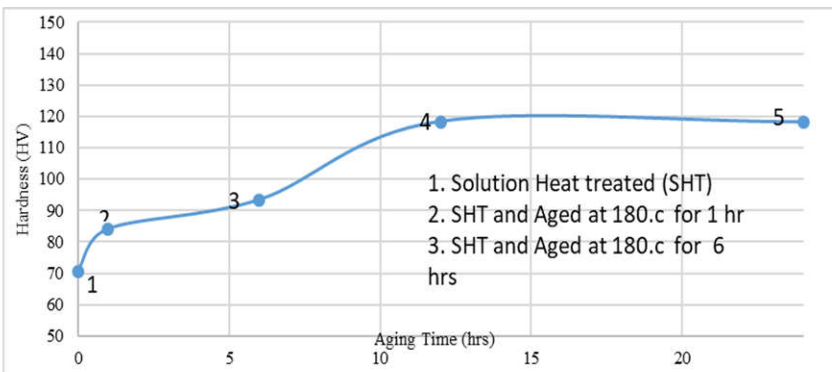

Figure 2 Influence of aging time on hardness of AA6061

Minimum hardness 70.65 HV/0.3 has been obtained for only solution heat-treated alloy work piece. For age hardened samples; minimum hardness was for 1 hour aged sample and then it increases until 12-hour time period. For 24 hour aged sample a small decrease in hardness value was observed as compared to 12-hour sample. Table 2 gives the average hardness values for various samples. The hardness increases with aging because due to formation of uniformly dispersed and extremely small particle of second phase in original phase matrix. These new phase small particles are known as precipitates.

Table 2 Hardness values for various samples

Sample	Hardness (HV/ 0.3)
Solution heat treated	70.65
Solution heat treated and aged for 1 hours	84.08
Solution heat treated and aged for 6 hours	93.35
Solution heat treated and aged for 12 hours	118.3
Solution heat treated and aged for 24 hours	118.1

These precipitates act as impurity in original phase matrix and reduce the possibilities of dislocation and increase the hardness of the material. In 24 hours' sample hardness decreased due to coalescence of these precipitates into larger particles and they provide resistance to dislocation. So due to over aging hardness again starts to decrease. In this work better hardness values have been obtained for 12 hours aged sample.

B. Effect of aging time on tool wear

Effect of solution heat treatment and aging on tool wear at a specific cutting speed have been plotted for different cutting speeds in Figure 3. Tool wear for non-heat treated workpiece has been also included in this plot for comparison purpose. It helps to differentiate the effect of aging on tool wear while machining was done on artificially aged and non-heat treated aluminum alloy. From the above plot it can be clearly seen that for non-heat treated workpiece tool wear is low at all speeds, but tool wear increases with increase in aging time. Aging process increases the hardness of the material and this increases tool wear by abrasive action of the hard constituents in the work piece material. This is due to increase in rubbing action of the tool in contact area with increasing cutting speed. It generates more heat at flank side and soften the edge, causes more wear of the tool.

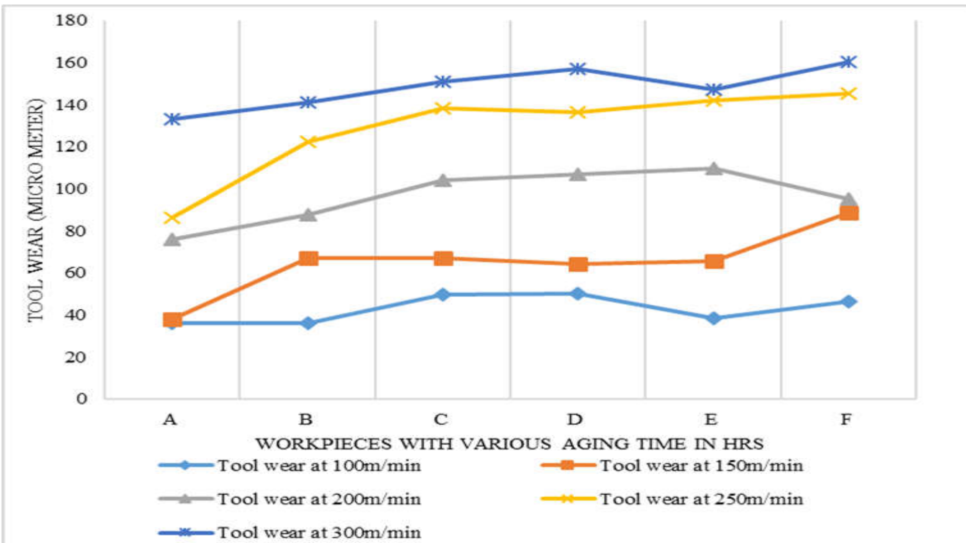

Figure 3 Effect of aging time on tool wear

IV. CONCLUSIONS

Hardness of the solution heat treated AA6061 is minimum with 70.65 HV/0.03, but when artificial aging have been done at various time for various work pieces it started to increase and maximum for SHT then aged for twelve hours. So aging time effects the precipitate hardening of the alloy. Tool wear increased with increasing in aging time period and found minimum for non-heat treated aluminium alloy work piece at all cutting speeds. Hardness of the aged work pieces were found more with increasing aging time in present work, so the harder constituent of these work piece material causes more tool wear by abrasive action. Tool wear also found to increase with increasing cutting speed in turning of artificially aged aluminium alloy by CNC turning Centre.

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