

Development of 7075 Aluminium Alloy for Improved Tribological Properties

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Abstract

The present investigation aims at the effect of Retrogression and Reaging (RRA) on dry sliding wear behavior of 7075 Aluminium alloys. The study has been done, where the retrogression and reaging (RRA) at temperatures of 160°C, 180°C, 200°C and 220°C for specimens of dry sliding wear and microstructure of 7075 aluminium alloy, which was received originally in the homogenized condition, has been investigated. After retrogression, the specimens are reaged to 120° C for period of 24 hours. Wear test were conducted on pin-on-disc type machine and effect of heat treatment on sliding wear behavior of aluminium alloys (7075) has studied under different load and sliding distances. For 16 specimens of different temperatures RRA treatment wear rates and coefficient of friction has been noted. The wear rate, coefficient of friction increases with increase in speed and load and it was concluded that the specimens RRA temperature at 180° C showed minimum wear rate, compared to co-efficient of friction and weight loss specimens at RRA temperature of 160°C, 200°C, and 220°C. The specimens of RRA temperature of 200°C showed the maximum wear rate, co-efficient of friction because from the hardness test, we can observe that this specimen has less hardness value compared to other RRA temperature specimens. The microstructure has been studied and discussed in details.

Key Words: Retrogression and Reaging (RRA), 7075 Aluminium Alloy.

1. Introduction

Retrogression and Reaging (RRA) treatment was first introduced by Cina [8] to increase the strength and corrosion properties of 7075 alloys. The first step followed in this process is homogenization where specimens are heat treated in a resistance furnace at a temperature of 460°C . The specimens are kept in the furnace at that temperature for 3 hours and then cooled slowly to room temperature [3]. The second step followed is to heat treat the specimen at the temperature of 120°C for the period of 24 hours. This process is called as reaging. The mechanical properties of Al-Zn-Mg alloy can be increased by the above two steps. The RRA treatment also increase the temperature range within the two phase ($\alpha+\eta$) region of the phase diagram.

The retrogression results in dissolution of G.P zones, followed by an increase in the volume fraction of η^1 and η precipitates and subsequent coarsening of these precipitates [10]. The G.P zone dissolution is responsible for the drop in yield strength and hardness at initial stages of retrogression. Rather, a fine dispersion of η^1 precipitates dominates T6 microstructure.

Aluminium (7075) alloys when subjected to a critical applied load undergoes either equal or higher wear rates. It is observed that it occurs due to fracture of precipitates [7]. Attempts have been made to examine the effects of aging on the sliding wear behavior of composites. It is seen that wear resistance decreases with increase in hardness [11].

The size of the grain boundary precipitates increases during the retrogression step [9]. The wear properties of Aluminium alloy depends on number of parameters such as shape, size, compositions and operating conditions such as loads, sliding speeds, temperatures etc.

2. Experimental Details

Aluminium Alloy Composition

The Composition in the aluminium 7075 alloy consists of materials like Zinc, Copper, Silicon, and Ferrous. Zinc is the primary alloying elements and has excellent properties like fatigue strength, average machinability. The composition details of aluminium matrix alloys is as shown in the Table .1

Table 1: Composition of Aluminium 7075 Alloy

Material	Percentage by Weight
Zinc (Zn)	5.88
Magnesium (Mg)	2.36
Copper (Cu)	1.53
Ferrous (Fe)	0.10
Silicon(Si)	0.04
Aluminium (Al)	90.09

Raw Material

The raw material used in this study was aluminium 7075 alloy semicircular block of radius 97.5 mm and thickness of 78 mm obtained from suitable source. The raw material obtained has been already homogenized at the temperature of 460⁰ C for the period of 3 hours and then cooled it to room temperature.

Specimen Preparation

Wear test specimen of diameter 6 mm and length of 30 mm has been machined out of the aluminium 7075 alloy semi-circular block by electric discharge machining.



Fig. 1: Shows the Sample Specimen of Diameter 6 mm and Length 30 mm

Heat Treatment

The specimens are kept in a furnace at a temperature of 460⁰ C for a period of 3 hours. The specimen are then taken out of the furnace and quenched in water to room temperature. These specimens are then reaged at a temperature of 120⁰ C for a period of 24 hours. After reaging the specimens are then air cooled to a room temperature to relieve residual stresses and to obtain even and fine microstructure.

The retrogression is a heat treatment process where the specimens are subjected to heat treatment between 140⁰C, 160⁰C, 180⁰C, 200⁰C and 220⁰C for the time of 3 minutes, 7 minutes, 11minutes and 15 minutes.

Wear Test

The properties such as wear rates, coefficient of friction has been found on pin-on-disc wear testing machine (Make: DUCOM Instruments) .The specimens made are according to ASTM G99 standards. The wear tests has been conducted at different sliding speeds of 350 rpm, 450 rpm, 550 rpm and 650 rpm and at the loads of 20N, 25N, 30Nand 35N. All experiments are conducted at room temperature. The disc and specimens are cleaned by Silicon graded emery paper. The constant running time taken for all the specimens is 20 minutes. The values of coefficient of friction and wear rates are directly taken by pin-on-disc machine, where the sliding speed of specimen has been calculated using formula,

$$S = \pi \times D \times N / 60000$$

The microstructure study has been done by Scanning Electron Microscope (SEM) VEGA TESCAN as shown in Fig.2. The parameters for SEM images are voltage of 25V, width varies from 11.52 mm to 15.35 mm, and magnification images of 300 X to 2000 X is taken. The specimen is subjected to RRA heat treatment at the temperatures of 160⁰C, 180⁰C, 200⁰C and 220⁰C. These are then subjected to mirror finish polishing and buffing to remove dirt and to make surface finish even and fine.



Fig. 2: Scanning Electron Microscope

Hardness Specimens

Hardness is the property to find crushing strength of the material [13]. The specimens are subjected to retrogression and reaging. The specimens are subjected to RRA heat treatment at temperatures of 160⁰C, 180⁰C, 200⁰C and 220⁰C for RRA time interval of 3 minutes, 7 minutes, 11 minutes and 15 minutes. The hardness test has conducted on Rockwell hardness machine of B-type.

3. Results and Discussions

Hardness Test

The Rockwell hardness machine measures based on the indentation insert in the material. The indentation insert is used for the hardness calibration. The indenter of 1/6th inch is used to pierce the material. The readings are taken by inserting indentation at three points and the average values of hardness are taken from these three points. The major and minor loads are selected and applied both at the same time. The dwell time for hardness test is 30 seconds for the application of the load. After the dwell time the major loads are removed but still the minor loads are maintained. The minor loads are applied initially to increase the accuracy. Table .2 shows the hardness value for the specimens at different RRA temperature and different RRA time.

Table 2: Hardness Values of RRA Temperature and RRA Time

	RRA Temperatures			
RRA Time	160 ⁰ C	180 ⁰ C	200 ⁰ C	220 ⁰ C
3 min	96	86	84	64
7 min	83	93	87	76
11 min	81	92	84	82.5
15 min	86	105	74	70.6

Wear Rates, Co-Efficient Of Friction and Weight Loss

The variation of wear rate, weight loss and co-efficient of friction with respect to different RRA temperatures is as shown in Fig. 3 to Fig 5. The variation of wear rate, weight loss and co-efficient of friction at different sliding distances and constant time are as in the graph plots. With increase in loads the value of wear rate, weight loss and co-efficient of friction increases [4].

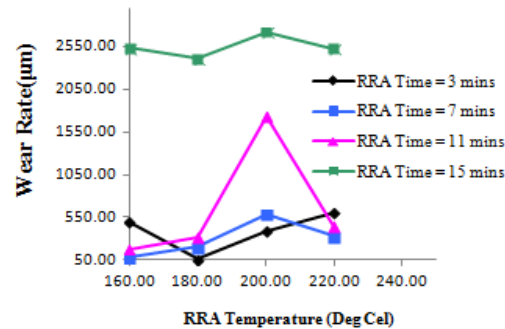


Fig. 3: Variation of Wear rate Vs RRA Temperature (Deg Cel)

From Fig. 3 shows the variation of the wear rate Vs RRA temperature. The specimens at RRA temperature of 180°C has the lowest wear rate when compared to different RRA time specimens of 3 minutes, 11 minutes, 15 minutes. It is seen from the Table .2 that hardness value is high for RRA 7 minutes specimen. i.e 93 HRB .Further the highest wear rate is at specimen of 220°C for the RRA time of 15 minutes as shown in fig. 3. This is because the hardness value for RRA 15 minutes specimen is 70.6 HRB from Table .2.

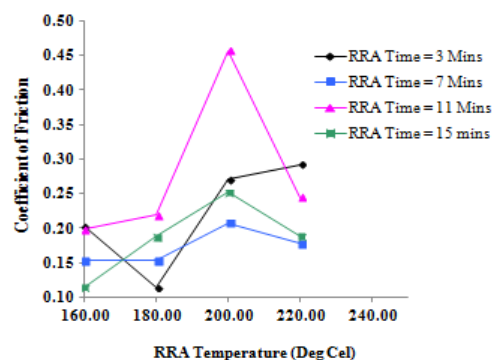


Fig. 4: Variation of Coefficient of Friction Vs RRA Temperature (° C)

From Fig. 4 shows the variation of the Co-efficient of Friction Vs RRA temperature. The specimen of RRA temperature at 180° C has lowest coefficient of friction. It can be attributed from Table .2 that hardness value of 180° C RRA temperature specimen has a hardness value of 86 HRB which

causes less co-efficient of friction. The highest value co-efficient of friction is for specimen at temperature of 200°C and RRA time of 11 minutes. From Table .2 it can be seen that the hardness value for the same RRA temperature time specimen is less because of which the co-efficient of friction is highest.

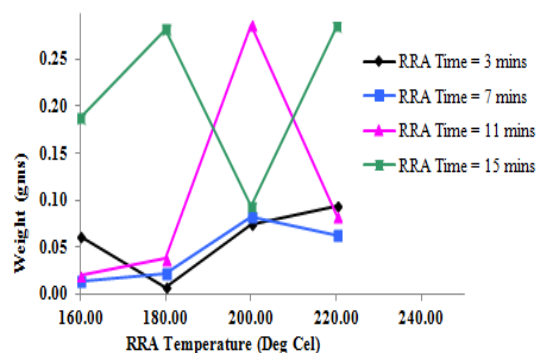


Fig. 5: Variation of Weight (gms) Vs RRA Temperature (Deg Cel)

From Fig. 5 shows the variation of the weight loss Vs RRA temperature. The weight loss is least at the temperature of 180°C for the RRA time of 3 minutes compare to other RRA temperature specimen. It can be observed from Fig.3 that the wear rate is least at this temperature compared to other RRA temperature specimens, because of this the weight loss is also less as weight loss is directly proportional to wear rate. The highest weight loss is at the temperature of 200°C for the RRA time of 11 minutes from Fig .5, the wear rate is high and also the hardness is less.

Scanning Electron Microscope (SEM) Images

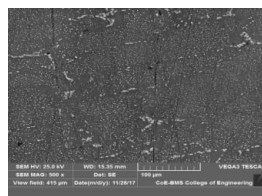


Fig. 6: SEM Image of Raw Material of 500X

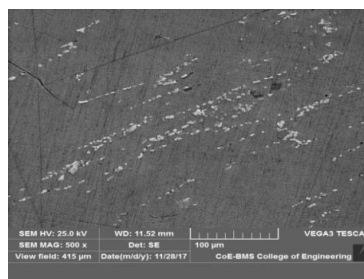


Fig. 7: SEM Image of RRA Temperature 160°C of 500X

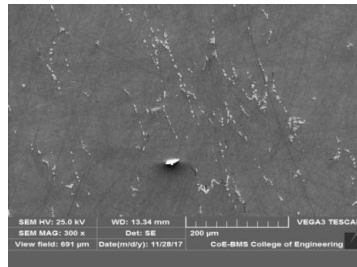


Fig. 8: SEM Image of RRA Temperature 180°C of 300X

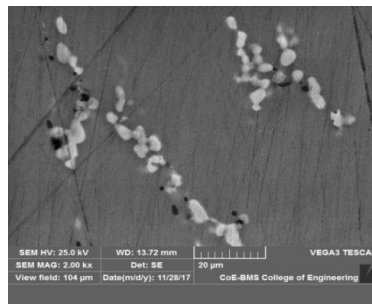


Fig. 9: SEM Image of RRA Temperature 180°C of 2000X

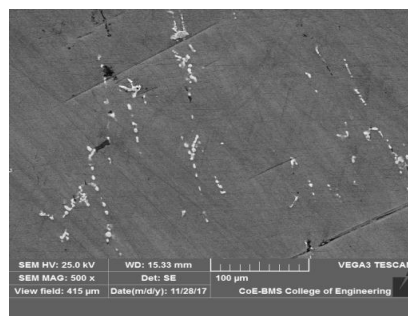


Fig. 10: SEM Image of RRA Temperature 200°C of 500X

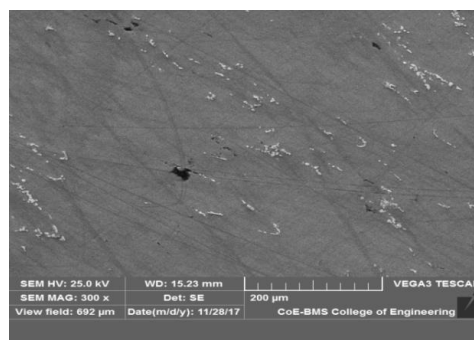


Fig. 11: SEM Image of RRA Temperature 220°C of 300X

Fig. 6 to Fig. 11 shows the Scanning Electron Microscope (SEM) images of 7075 Al alloys. It has observed that the coarse grains are formed in RRA treated samples and distributed finely on the surface.

From Fig .6 it can be seen that in raw materials the precipitates are distributed evenly in the aluminium alloy .It has observed that from Fig .7 to Fig .11 shows the SEM of grain structure in Al 7075 alloys. The SEM was taken for different RRA temperature treated conditions i.e 160⁰C, 180⁰ C, 200⁰C and 220⁰C. It has been observed that the precipitates are formed at the grain boundaries of all the RRA temperatures specimens. The SEM also reveals the presence of medium to coarse and closely spaced precipitates in the grain boundaries and fine precipitates within the grains. It can also seen from the SEM that the precipitates are discontinuous and coarser along grain boundaries.

4. Conclusion

It can be concluded that the lower wear rates weight loss and co-efficient of friction can be seen at 180⁰C RRA temperature specimen compared to other RRA temperatures such as 160⁰C, 200⁰C and 220⁰C. This attributes to the increase in the hardness of the material at that temperature as seen from Table .2. The wear rates, weight loss and co-efficient of friction is high at 200⁰C RRA temperature compare to the specimens of other RRA temperature. This is because the low hardness of the material at the 200⁰C RRA temperature as shown in Table .2.

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