COMPARATIVE STUDY OF TRIBOLOGICAL CHARACTERISTICS OF AA2024+10% FLY ASH COMPOSITE IN NON-HEAT TREATED AND HEAT TREATED CONDITIONS

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Abstract

There has been search for the low cost and low density reinforcements for reducing the cost of composites. One prospective reinforcement in this regard is the fly ash, which is abundantly available as a waste product from thermal power plants. Because of unique nature of physical and chemical properties of the fly ash it is tried as reinforcement by many researchers in the recent past. In the present investigation composite used contains fly ash particles [10% by wt] reinforced with wrought aluminium alloy AA2024. The composite is tested for tribological behaviour in the Non-Heat Treated [NHT] and Heat-Treated [HT] conditions under different working parameters in a pin-on-disc tribometer. The results of the experiment indicate that the dispersion of fly ash particles in the AA2024 alloy matrix would increase the wear resistance of matrix alloy. It's observed that a significant improvement in wear performance is achieved by heat treating the composite. The water quenched specimen showed a better properties as compared to air cooled and NHT counterparts.

Keywords: *fly ash, composite, heat-treatment, wear and microstructure*

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1. INTRODUCTION

With the advancement in science and technology the human life has improved tremendously due to newer and better materials in all walks of life. Initially man used materials naturally available like wood and stones then he learnt to weave natural fibers like cotton and silk to make cloth. Slowly he discovered iron and copper, later he started to make new materials that are not found readily in nature. With the invention of plastics conventional materials were replaced because of inherent drawbacks like heavy weight and strength loss due to corrosion. Of late the scientists and researchers have started mixing materials (matrix and reinforcements) with different properties in a new way so as to make new materials which have good properties of the constituent without having the inherent weakness or disadvantages of the individual materials. These new materials are called as composite materials [1].

Among many types of matrix materials for composites aluminium and its alloys is most favorite material for producing metal matrix material. Aluminium-alloy-based composites are very attractive on account of their processing flexibility, wide range, low density, high wear resistance, high thermal conductivity, heat-treatment capability, improved elastic modulus and strength, stiffness and dimensional stability [2, 3].Many types of reinforcements have been tried out in the recent times like B_4C[4,5], Al_2O_3[6,7], SiC[8,9,10], AlNp[11], TiC[12]for producing particulate composite. However the cost of producing composites with such reinforcements is high and this limits the use in many engineering applications.

Keeping in mind the environmental hazards of fly ash, its low cost, low density and abundant availability as waste by product from the combustion plants it is used by some researchers [13, 14-17, 18-20] to widen the engineering applications of particulate composites.

Incorporation of fly ash particles in aluminium metal/alloy will definitely promote the use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminium and thereby, reducing the cost of aluminium products[16].

These aspects give a hint for the need of further research on aluminium fly ash composites to explore the possible opportunities in engineering applications.

Aluminum-fly ash composites have potential applications as covers, pans, shrouds, casings, pulleys, manifolds, valve covers, brake rotors, and engine blocks in automotive, small engine and the electromechanical industry sectors [13].

2. EXPERIMENT

2.1 Test Composite Material

The precipitator type fly ash is used as reinforcement which is a gray colored fine powder with the particle size below 45 µm and with density 1.1902 gm/cc. The aluminium alloy selected for the matrix material is AA2024.The density of as received alloy was 2.77 gm/cc. Conventional motorized stir casting set up was used [21] to produce the AA2024 alloy based fly ash[10% by wt] composite.

AA2024+10% fly ash composite specimens were subjected to heat treatment by using an electrical resistance furnace equipped with programmable temperature controller with an accuracy of ±2^{o}C for both solutionizing and aging. Solutionizing is carried out at a temperature of 350,450 and 530^{o}C for same duration of 90 minutes followed by quenching in air (37^{o}C) and water media (25^{o}C). Artificial aging is carried out at 175^{o}C for 60 minutes [22]. The calculated density as per Archimedes principle for AA2024+10% fly ash composite is found to be 2.693 gm/cc and 2.685 gm/cc for NHT and HT condition respectively [23].

2.2 Tribometer

To evaluate the sliding wear behaviour of AA2024+10% fly ash composite specimens, experiments were conducted in pin-on-disc type wear and friction monitor [DUCOM, India make; Model: TR-201CL] supplied with data acquisition system as shown in Fig 1.This tribometer is specifically suitable for fundamental wear and friction characterization. Following are the technical specifications of the machine:

Disc : Size (mm) :100 x 6
Material : Hardened ground steel (EN-31), 65 HRC
Rotational speed : Min=80 rpm and Max= 800 rpm
Motor : AC motor, 230 V, 0.37 kW
Wear track Diameter: Min=20 mm and Max=80mm
Normal load : Up to 100 N Max

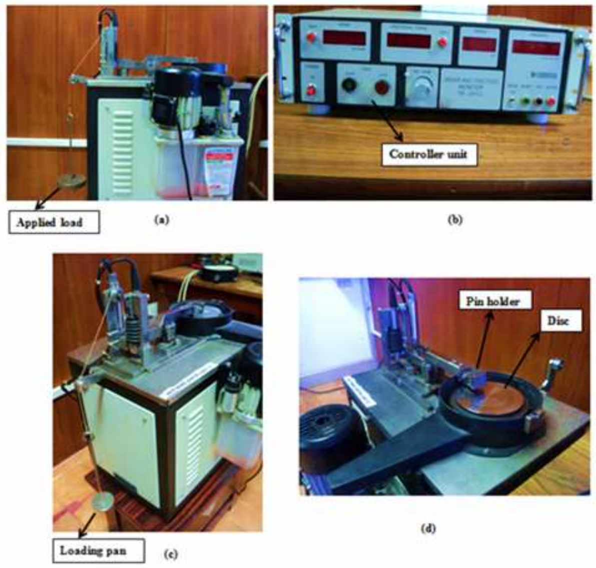


Fig 1 Pin-on disc apparatus

2.3 Wear Test

The wear tests were conducted as per ASTM G-99 standards in air under the laboratory condition having a relative humidity of 80 to 85% and temperature ranging between 25 to 29^{o}C.The duration of single test was 6 hrs. The test specimen contact surface and disc surface were polished with silicon carbide emery paper of 600 grit for smooth contact between them prior to the conduction of each test. The specimens were cleaned with ethanol solution before and after each test. After each 1hr during the test the specimen mass was measured to know the mass loss by using a high precision electronic weighing machine (Infra digital balance, Model: IN2011) having a resolution of 0.001mg. Also the track of disc and specimen surface was regularly cleaned by soft cotton cloth to avoid the entrapment of wear debris.

The test specimen used was a cylindrical pin (8 mm diameter and 27 mm length) that was held with its axis perpendicular to the surface of the disc, and one end of pin slid against the disc in a dry friction condition, under a constant axial load applied with a dead weight. For testing specimens in both NHT and HT conditions, a constant sliding velocity of 0.628 m/sec (200 rpm) is selected. The applied normal load was 10, 25 and 35 N.

The parameters of wear like wear rate, volumetric wear rate and specific wear rate were determined based on the mass loss Δm, of the specimen that is measured at the end of each 1 hr during the test having one specific condition of load, speed and sliding distance (SD).

The *wear rate* is calculated by expression, $W_r = \Delta m/SD$-- (1)

It is defined as the mass of material removed per sliding distance for a given load. It can be used as a quantitative comparative value for wear resistance.

Volumetric wear rate is given by, $W_v = \Delta m/\rho.t$ ------------ (2)

Equation (2) for volumetric wear rate relates the mass loss of specimen with the material density and abrading time.

Specific wear rate is determined by, $W_S = W_v/V_{S.} F_n$ ------ (3)

Where the V_S is the velocity of sliding and F_n is the normal force applied externally.

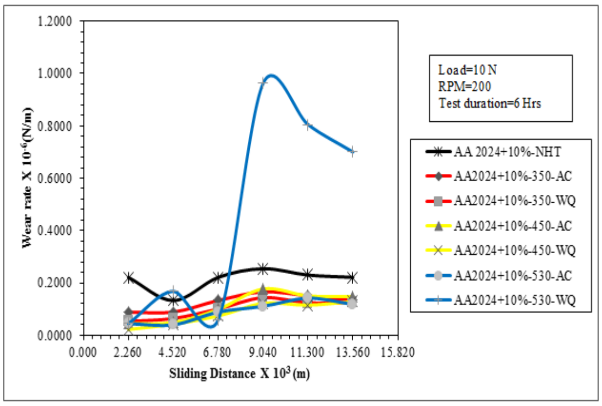
3. RESULTS AND DISCUSSION

Based on the wear test various graphs have been plotted for comparative analysis on wear performance between the NHT and HT 2024+10% fly ash composite. These plots are shown in Fig 2-6.

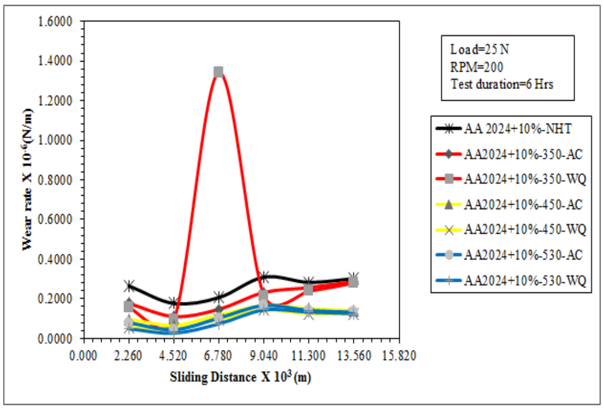
The Variation of wear rate of AA2024+10% fly ash composite with sliding distance under NHT and HT conditions is shown in Fig 2(a-c). The wear rate increases at lower siding distances and it remains almost constant at higher sliding distances for 10 N and 25 N loads. But at 35 N load wear rate decreased as the sliding distance is increased and it remained constant for sliding distance more than 9000 m. The wear resistance of specimen which was heated to 450^{o}C and water quenched is better as compared to others. Also the wear rate as a function of normal load is low for the same specimens comparatively, but is having an increasing trend as the normal load is increased which is evident from Fig 3.

The specific wear rate increases for increase in load and decreases for increase in temperature for a specific load for air cooled and water quenched conditions. Also it kept increasing for increase in load for non-heat treated conditions. As observed from Fig 4(a-c) that specific wear rate is lowest for water quenched condition as compared to air cooling and non-heat treated conditions at all the loads and temperatures except at 10 N, 530^{o}C and 25 N, 350^{o}C [23].

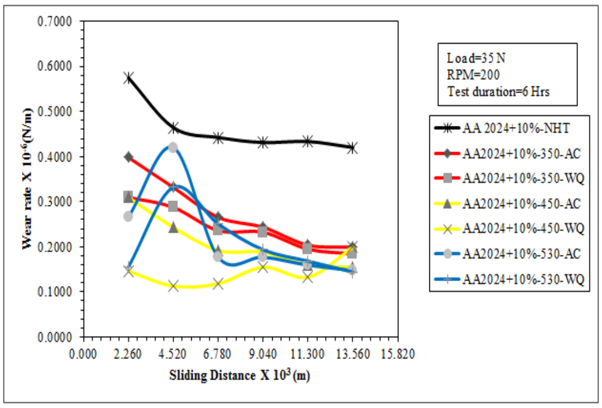
Co-efficient of friction for NHT composite increases upto 25 N but from there it decreases for further increase in load. This composite is found to have lowest coefficient of friction for all the loads as compared to other HT category specimens [Fig 5]. Variation of co-efficient of friction of AA2024+10% fly ash composite with sliding distance in NHT and HT (with different heated temperature and cooling media) conditions is shown in Fig 6(a-c). Co-efficient of friction was higher for water quench as compared to air cooled and NHT specimens. It remained almost constant for increase in sliding distance for air cooled and NHT specimens. Eventually it increased successively by small amounts for water quenched specimens with respect to increase in sliding distance.



(a)



(b)



(c)

Fig-2: Variation of wear rate of AA2024+10% fly ash composite with sliding distance under NHT and HT conditions

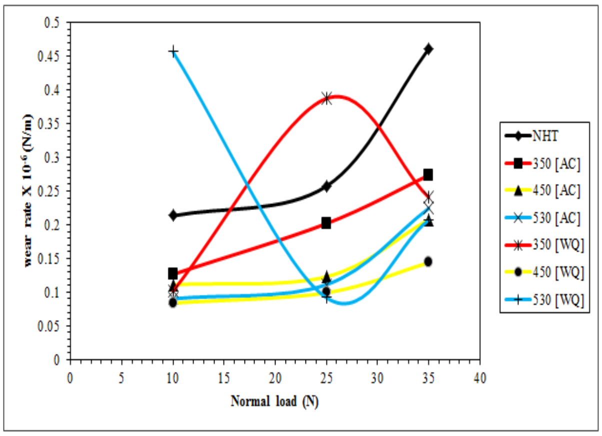
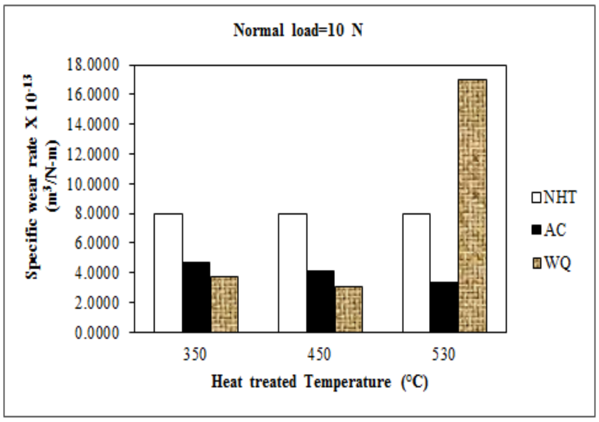
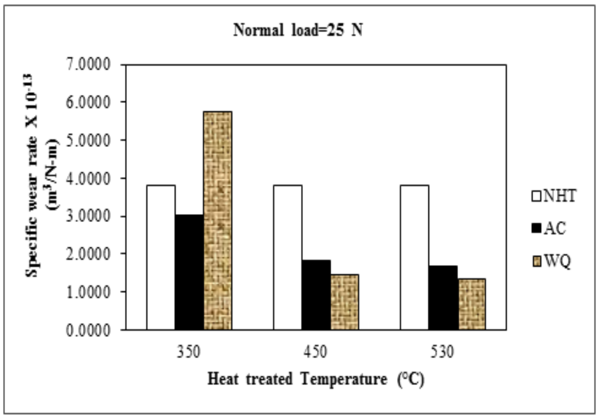


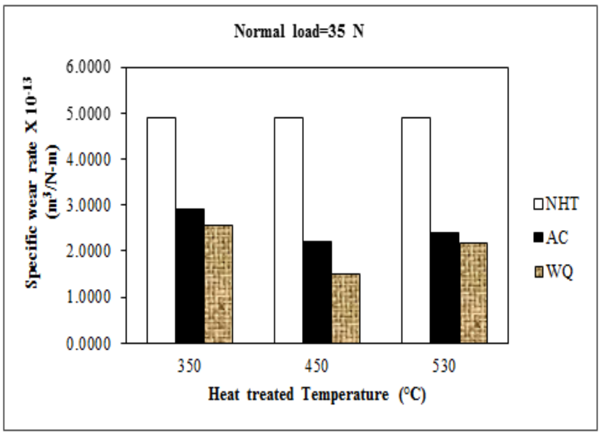
Fig-3: Variation of wear rate of AA2024+10% fly ash composite with normal load under NHT and HT conditions



(a)



(b)



(c)

Fig-4: Variation of specific wear rate of AA2024+10% flyash composite in NHT and HT (with different heated temperature and cooling media) conditions

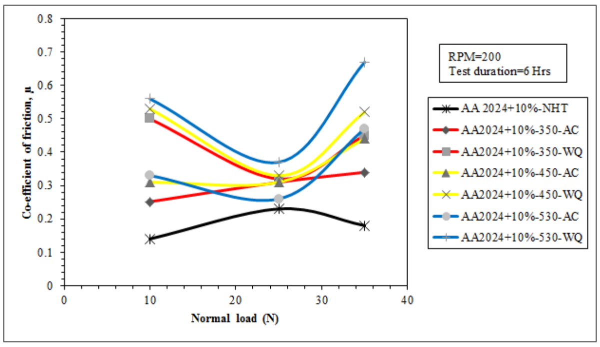
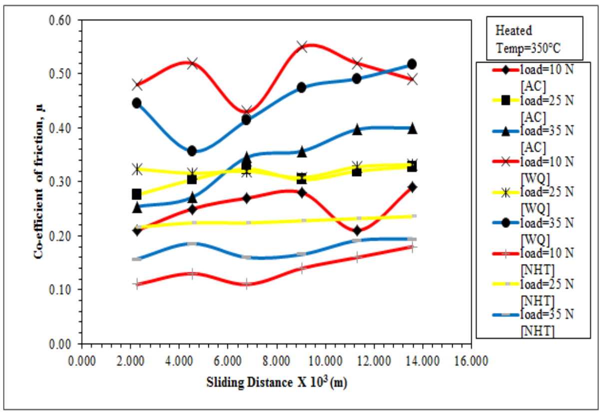
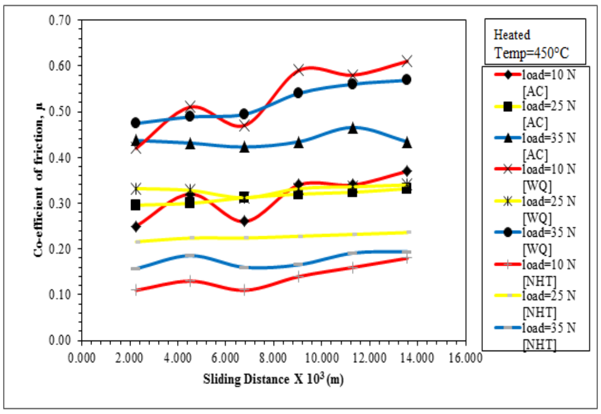


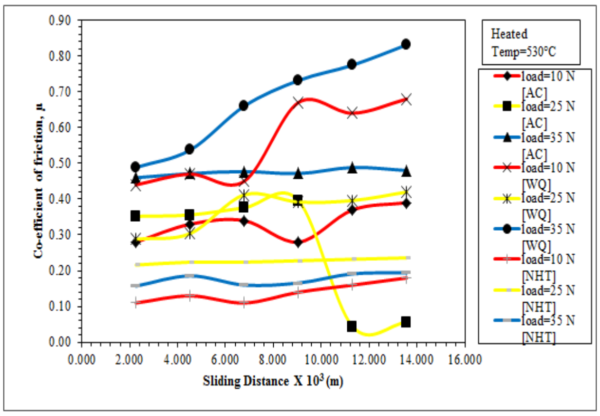
Fig-5: Variation of co-efficient of friction of AA2024+10% fly ash composite with normal load in NHT and HT (with different heated temperature and cooling media) conditions



(a)



(b)



(c)

Fig-6: Variation of co-efficient of friction of AA2024+10% fly ash composite with sliding distance in NHT and HT (with different heated temperature and cooling media) conditions

CONCLUSIONS

- Heat treated AA2024+10% fly ash composite show superior wear characteristics as compared to non-heat treated category, specifically the wear performance was better for water quenched specimens as compared to air cooled and non-heat treated ones.
- The specimens of NHT and HT category, at 35 N load shows that the wear rate decreasing as the sliding distance is increased and it remained constant for sliding distance more than 9000 m.
- Wear rate as a function of normal load is low for the water quench specimens, but is having an increasing trend as the normal load is increased.
- The specific wear rate is found to be lowest for water quench specimens as compared to NHT and air cooled conditions.
- NHT composite is found to have lowest coefficient of friction for all the loads (10, 25 and 35 N) as compared to other HT category specimens.
- Co-efficient of friction was highest for water quench as compared to air cooled and NHT specimens as the sliding distance in increased.

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