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Effect of Heat Treatment on Slurry Erosive Wear Behaviour of Al 6061 Based Composites

Abrar Ahamed[a*], A. R. Anwar Khan[b]

[a]*Faculty of Mechanical Engineering, Birla Institute of Technology, Offshore Campus, Ras Al Khaimah, UAE.*
[b]*Faculty of Mechanical Engineering, Ghousia College of Engineering, Ramnagaram, Karnataka, India.*

Abstract: In the present investigation, Titanium di oxide (TiO2) reinforced Al 6061 composites fabricated using liquid metallurgy route with varying proportions by weight viz 4, 6, 8 and 10 percentage were subjected to precipitation hardening heat treatment. The performance of heat treated Al 6061 based Titanium di oxide composites in slurry erosive environment was examined. The slurry consists of equiaxed sand particles of size approximately 600 µm in 3.5%NaCl solution. The slurry erosive wear studies on heat treated Al 6061 alloy and Al 6061-TiO2 composites were carried out at under different test conditions. It was observed that with an increase in aging duration for all the quenching medias and for all the given test conditions there is a reduction in slurry erosive wear rate of both the base alloy and the composites, however ice as quenching media has a profound effect on the slurry erosive wear rate of both the base alloy and the composites studied.

Keywords: Aluminium 6061 composites; solutionising; ageing; slurry erosive wear.

1. Introduction

In recent years metal matrix composites (MMCs), are gaining widespread popularity in several technological sectors owing to their excellent corrosion and wear resistance, higher fatigue life, good high temperature oxidation resistance in addition to being light in weight when compared with conventional alloys. A metal matrix composite consists of matrix and a ceramic reinforcement in various forms such as whiskers, particulates or fibers. They can be tailored to have superior properties such as high specific strength and stiffness, increased wear resistance, enhanced high temperature performance better thermal and mechanical fatigue and creep resistance than those of monolithic alloys. Currently researchers are focusing on development of aluminium [1-3], copper [4], magnesium [5], titanium [6] based metal matrix composites and have been exploring their possible applications in several high-tech areas. However, currently aluminium and its alloys are being chosen as matrix alloy to develop metal matrix composites specially for tribological applications [7].

Aluminium alloys have excellent mechanical properties coupled with good corrosion resistance. However, they possess poor wear and seizure resistance. To improve the above said properties, researchers have successfully dispersed various hard and soft reinforcements such as SiC, Al_2O_3, flyash, glass, WC, graphite, mica, coconut shell char in aluminium alloys by different processing routes [8-10]. Of all the processing routes, liquid metallurgy method is the most sought after owing

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*Corresponding author; e-mail: abrar_gce@rediffmail.com
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to its several advantages such as economical, mass production, and creating near net shaped components [11]. Use of TiO_2 as reinforcement in aluminium alloys has received little attention although it possesses high hardness and modulus with superior corrosion resistance [12]. Of all the aluminium alloys, 6061 is quite popular choice as a matrix material to prepare metal matrix composites owing to its better formability characteristics and option of modification of the strength of composites by adopting optimal heat treatment [8]. In recent years, aluminum alloy based metal matrix composites (MMCs) are being explored as a potential materials in several interesting applications such as piston, connecting rod, contactors, where sliding is a key component [9]. Further, meager information is available as regards the effects of heat treatment on the modifications of mechanical, tribological and corrosion behavior of aluminium based metal matrix composites [13-15]. Hence, the present investigation is aimed at developing aluminium based metal matrix composites with TiO_2 as reinforcements and to characterize their microstructure, hardness and slurry erosive wear properties after subjecting both the matrix alloy and composites to heat treatment.

2. Experimental set up

Aluminum 6061 was used as matrix material owing to its excellent mechanical properties coupled with good formability and its wide applications in industrial sector.

Titanium dioxide was chosen as reinforcement owing to its high hardness and low co-efficient of thermal expansion. TiO_2 is highly wear resistant and also has good mechanical properties, including high temperature strength and thermal shock resistance [12]. Titanium dioxide as reinforcement was added to Aluminum 6061 matrix in varying proportions ranging from 4wt.% to 10wt.% in steps of 2wt.%.

The detailed discussion on the method of preparation of the Al 6061 based TiO_2 reinforced composites is explained else where [16].

After casting, the test specimens were prepared by machining from both Al6061 alloy and Al6061-TiO_2 composite for characterizing its microstructure, hardness and slurry erosive properties after heat treatment process.

The cast samples of both Al6061 alloy and its composites were subjected to heat treatment in a muffle furnace as shown in Figure 1. The samples were solutionized at 550°C for duration of two hour and quenched in three different quenching medias viz., ice, water and air. Both natural and artificial ageing was adopted after quenching. Artificial ageing was carried out at 175°C for different aging hours ranging from 4 to 10hrs in steps of 2hrs for ice, water and air quenched samples.

The detailed discussion on the procedures followed in carrying out microhardness and slurry erosive wear tests of the Al 6061 based TiO_2 reinforced composites subjected to heat treatment is explained elsewhere [16]. The flow chart of explaining the procedures followed in the present work is shown in Figure 2.

Figure 1. Photograph of muffle furnace used for heat treatment.

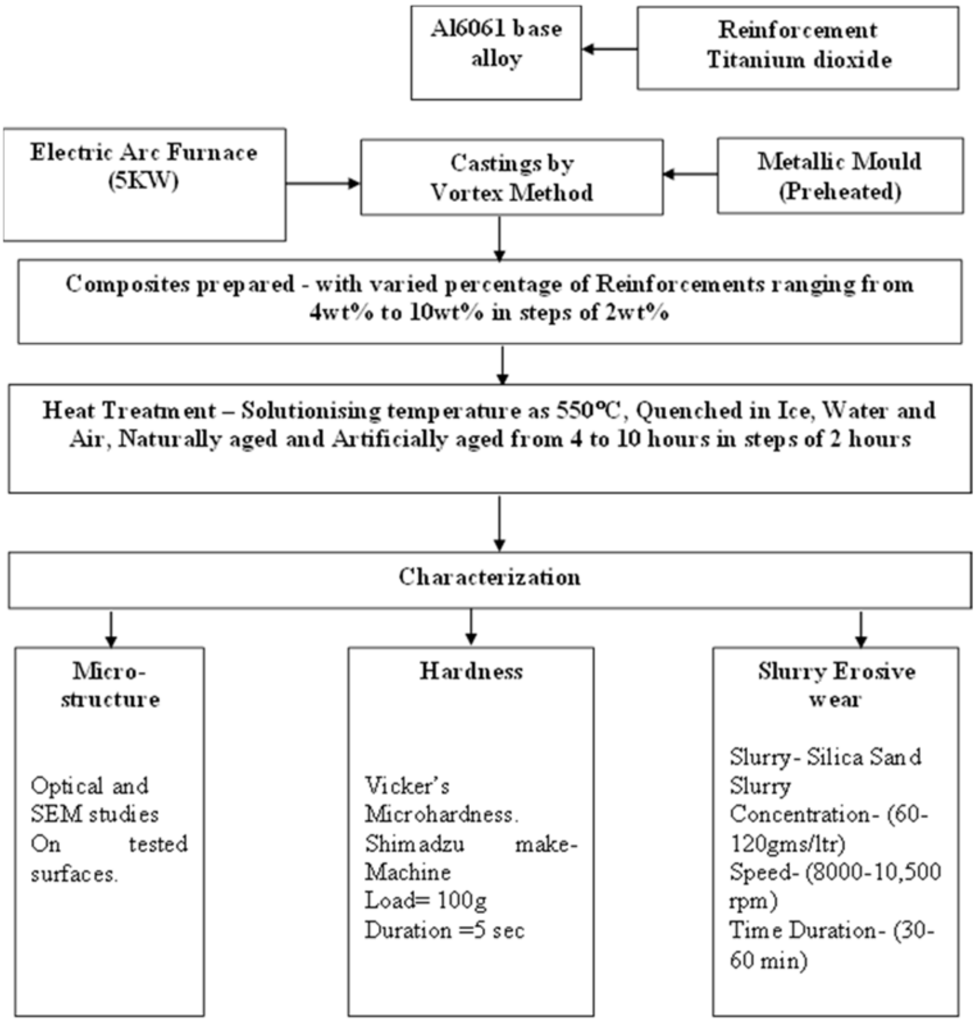
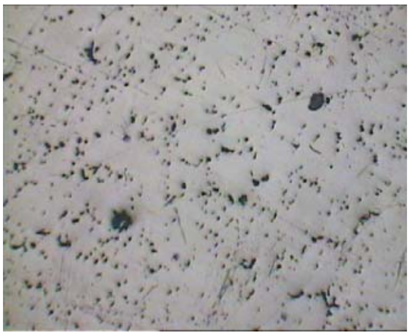


Figure 2. Flow chart showing the steps involved in the fabrication and testing of the materials

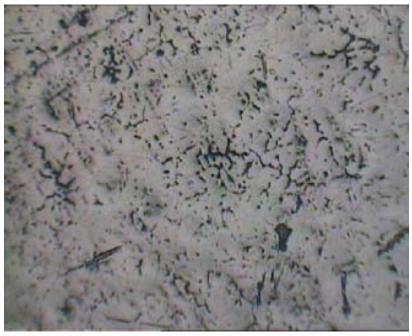
3. Results and discussion

3.1. Microstructure

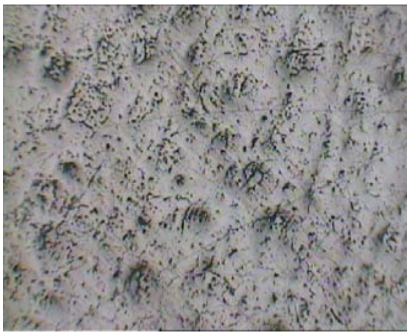
The effect of heat treatment on the microstructure of the composites is shown in Figure 3. The Quenching media has a profound influence on the microstructure. Among all the quenching medias studied, it is observed that Ice quenching results in fine dispersion of the intermetallic phases and the dispersiod in the matrix. The higher degree of homogeneity of the distribution in case of ice quenching can be attributed to the fact of rapid rate of cooling, which will have strong tendency to produce more extent of the intermetallic phases [17]. The uniformity in the distribution of the above phases will have a strong influence in improving the mechanical properties of the composites, which will be discussed in the next section.



(a) Al6061-8wt.% TiO_2, Air Quenched



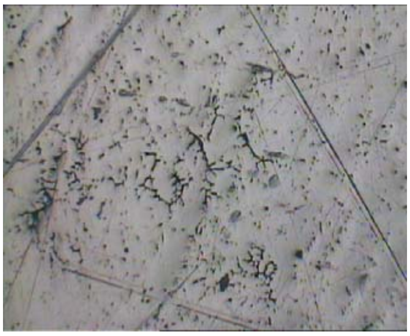
(b) Al6061-8wt.% TiO_2, Water Quenched



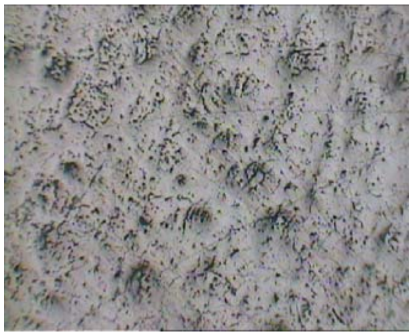
(c) Al6061-8wt.% TiO_2, Ice Quenched

Figure 3. Microphotographs of Al 6061-8wt.%TiO_2 composite for different quenching medias, solutionised at 550°C and artificially aged at 10 hrs.

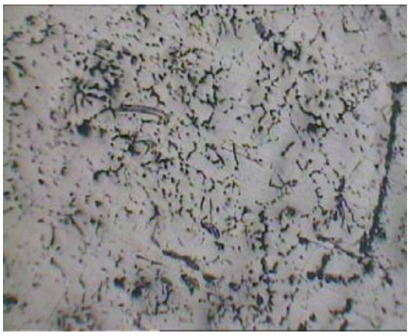
Further in addition to the quenching media adopted, the aging duration dictates to a great extent the microstructure of the composite as shown in Figure 4. Increased aging time results in greater degree of precipitation of the intermetallic phases. This can be attributed to the fact that increased aging time will result in increased energy, which promotes higher rate of dispersion of the intermetallic precipitates [18].



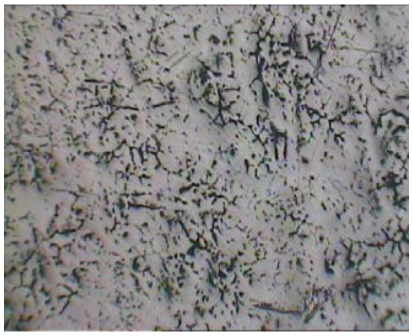
(a) Al6061-6wt.% TiO_2, Ice Quenched, 4hrs



(b) Al6061-6wt.% TiO_2, Ice Quenched, 6hrs



(c) Al6061-6wt.% TiO_2, Ice Quenched, 8 hrs



(d) Al6061-6wt.% TiO_2, Ice Quenched, 10 hrs

Figure 4. Microphotographs of heat treated Al 6061-6wt.%TiO_2 Composite for different artificial aging durations, Ice quenched and solutionised at 550°C.

3.2. Microhardness

Figure 5 shows the effect of quenching media on the microhardness of the cast Al6061-TiO_2 composites. It is evident that for a given content of TiO_2 in the matrix alloy, ice quenching has resulted in the maximum hardness of the composites under identical heat treatment conditions. Air quenching has resulted in least improvement of microhardness of the composites for a given content of the reinforcement under identical heat treatment conditions. However, an intermediate levels of improvement in the microhardness of the composites is observed on water quenching when compared to ice and air quenching.

The drastic improvement that is obtained on ice quenching of composites can be mainly attributed to the faster rate of cooling that exists during ice quenching when compared with water and air quenching. This accelerated cooling will not allow the precipitation of inter metallic precipitations from the super saturated solid solution during the quenching process [19].

Figure 6 shows the variation of microhardness of Al6061-TiO_2 composites with increased aging time under identical heat treatment conditions. It is observed that for a given quenching media an increase in aging time increases the microhardness of the composites. In most of the cases it is observed that with an increase in ageing duration after 8 hrs will result in reduction of microhardness of both the matrix alloy and its composites under identical test conditions. The improved microhardness of the composites with increased aging time can mainly be attributed to the fact that increased aging duration will accelerate the kinetics of precipitation hardening in composites. This phenomenon will result in larger extent of the formation of inter metallic precipitates in a fine state of dispersion, which in turn obstructs the motion of the dislocation there by leading to improved hardness. However, very long aging duration will result in precipitation of

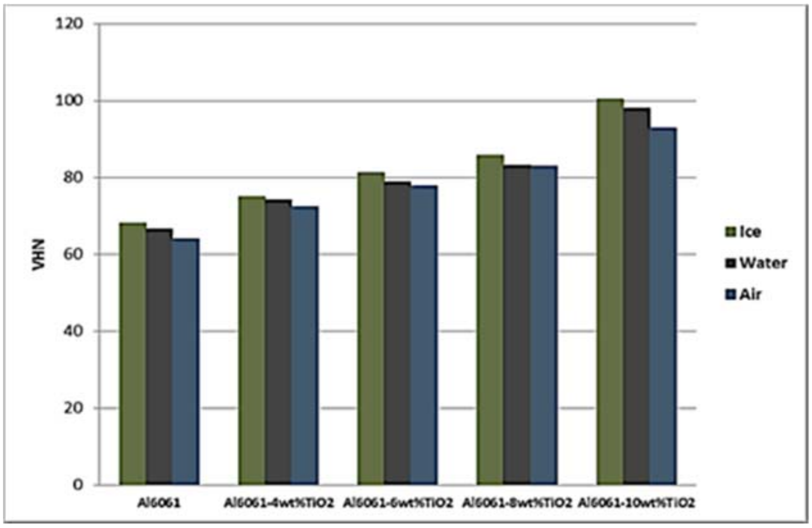


Figure 5. Effect of quenching media on microhardness of cast Al6061 and Al6061-TiO_2 composites for a given ageing duration of 10 hours

coarser inter metallic precipitates. The formation of the coarser inter metallic precipitates is mainly due to the growth of the formed inter metallic precipitates. Coarser inter metallic precipitates leads to reduction in hardness [20].

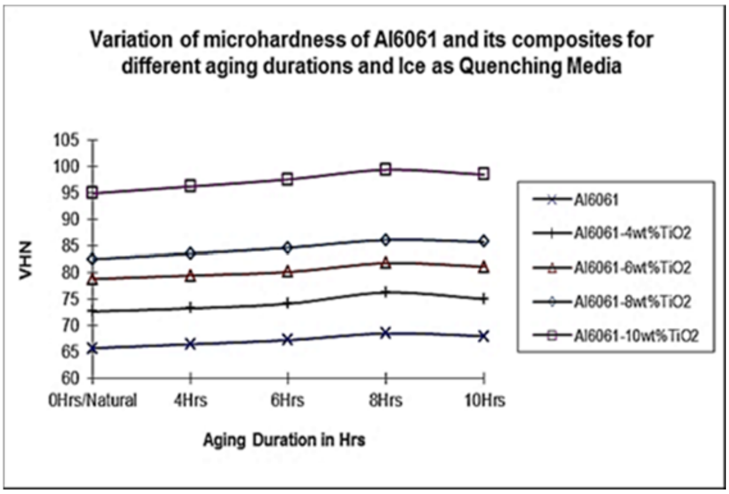
3.3. Slurry Erosive Wear results

Figure 7 shows the effect of quenching media on the slurry erosive wear rate of both the cast base alloy and the cast composites. Ice as quenching media has lower slurry erosive wear rate in all the test conditions when compared to water and air quenched specimens. This can be attributed to the fact that ice quenched specimens possess higher hardness when compared to the other two quenching medias as discussed in the earlier section.

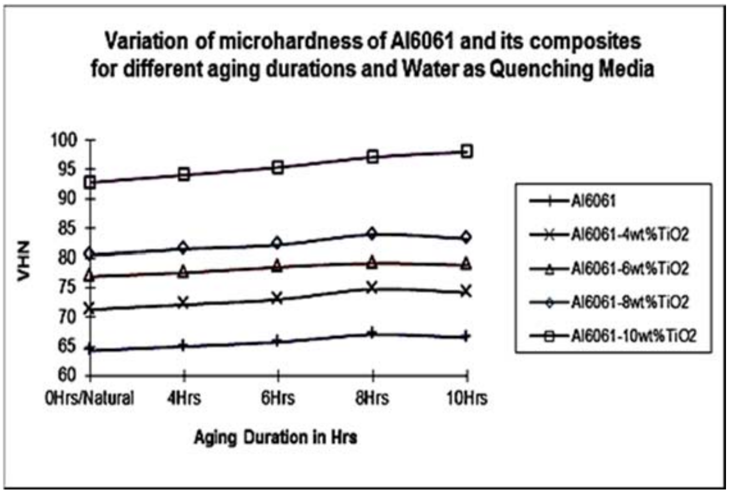
Figure 8 shows the SEM photographs of the damaged surfaces of the heat treated samples subjected to slurry erosive wear test under identical test conditions. It is observed that the erosion is quite severe in case of ice quenched sample when compared to the other two medias of quenching. Further, some salt deposits are observed over water quenched and ice quenched samples under identical test conditions which will retard the rate of damage on the samples. This can be attributed to the improvement in slurry erosive wear resistance of ice quenched samples.

There is a significant reduction in slurry erosive wear rate of both the base alloy and the composites with an increase in aging duration for all the quenching medias and all the test conditions as shown in Figure9. This can be attributed to the fact that with an increase in aging duration there is an enhancement in the hardness of both the cast base alloy and the cast composites as explained in the earlier section.

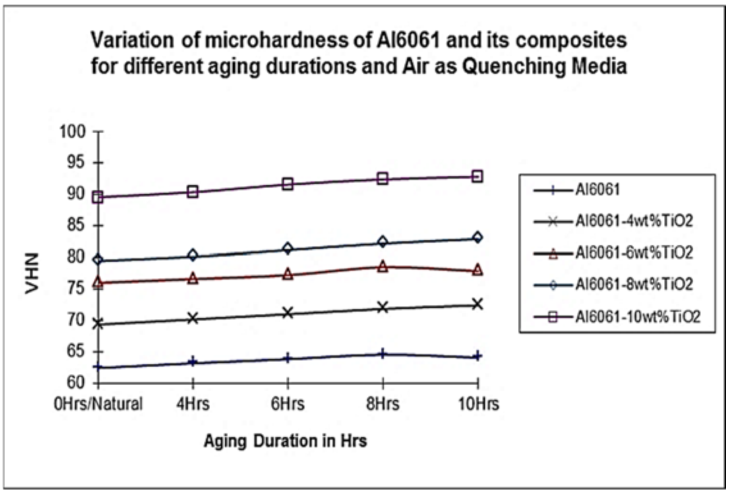
However, it is observed that under identical test conditions Al 6061-TiO_2 composites exhibit better slurry erosive resistance when compared to Al 6061 alloy. This can be attributed to an improvement of hardness of the composite with an increase in percentage reinforcement [16].



(a) Ice as quenching media

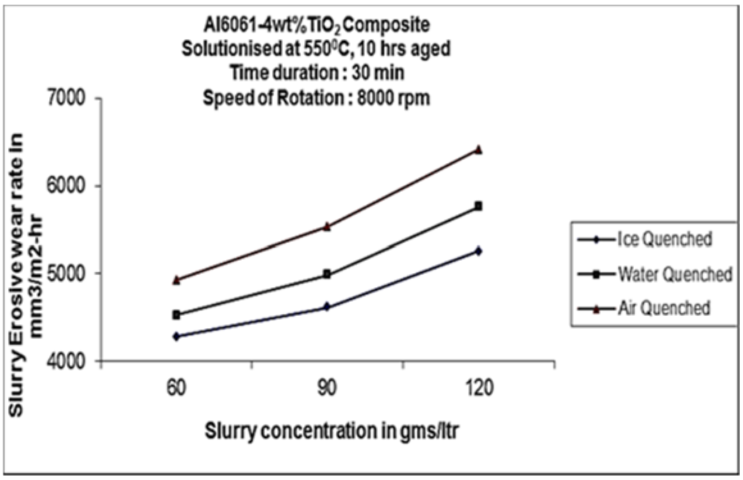


(b) Water as quenching media

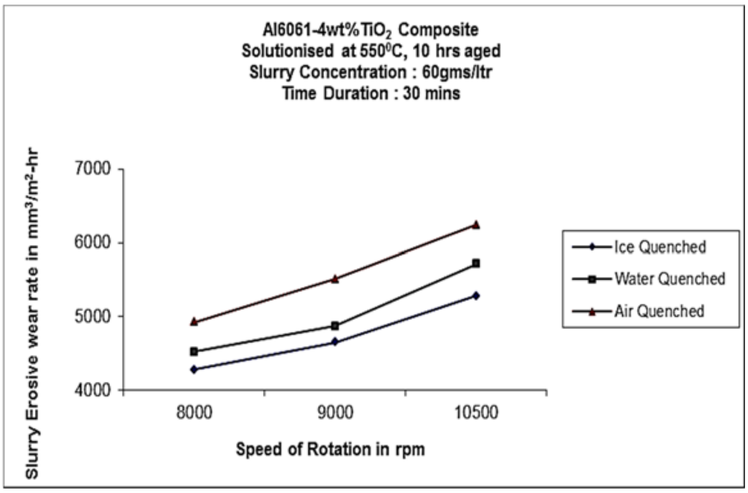


(c) Air as quenching media

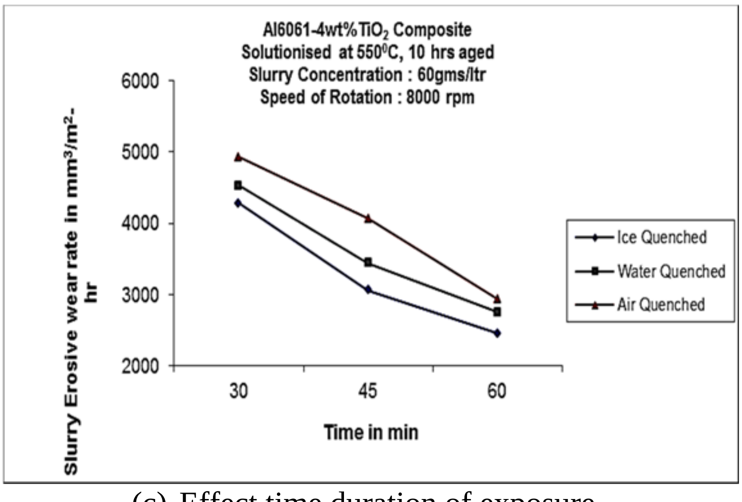
Figure 6. Variation of microhardness of Al6061 and Al6061-TiO_2 composites with increased aging time



(a) Effect of slurry concentration

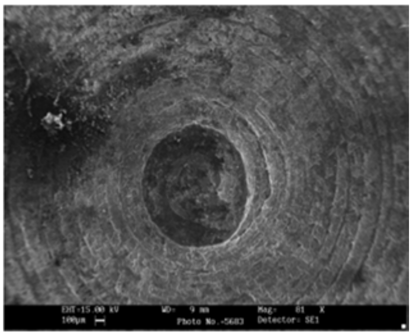


(b) Effect of speed of rotation

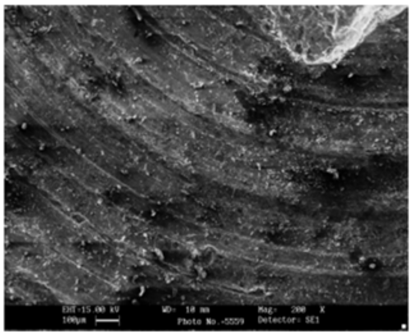


(c) Effect time duration of exposure

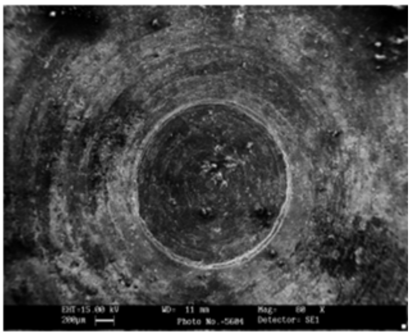
Figure 7. Variation of Slurry erosive wear rate of cast Al6061-4wt.% TiO_2 composite for different quenching medias under identical test conditions.



(a) Air Quenched



(b) Water Quenched



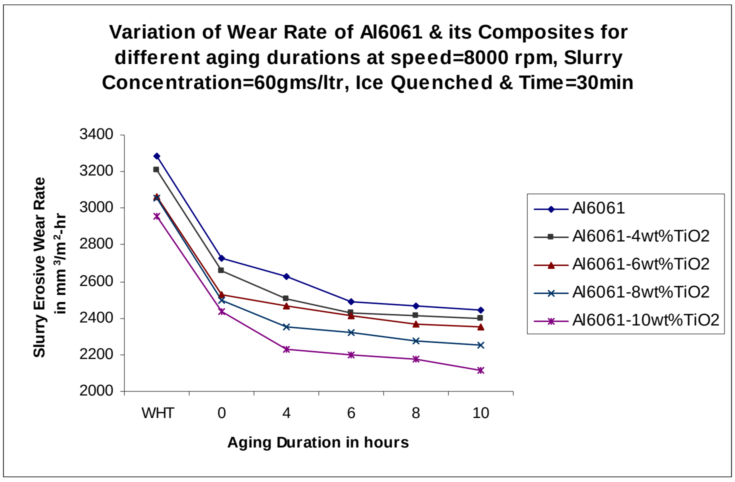
(c) Ice Quenched

Figure 8. SEM photographs of worn slurry erosive wear test specimens for different Quenching Medias.

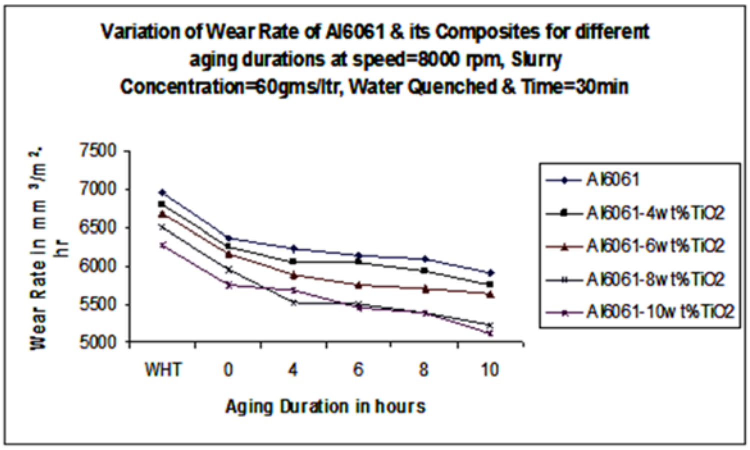
4. Conclusions

The following conclusion can be drawn within the scope of present investigation:

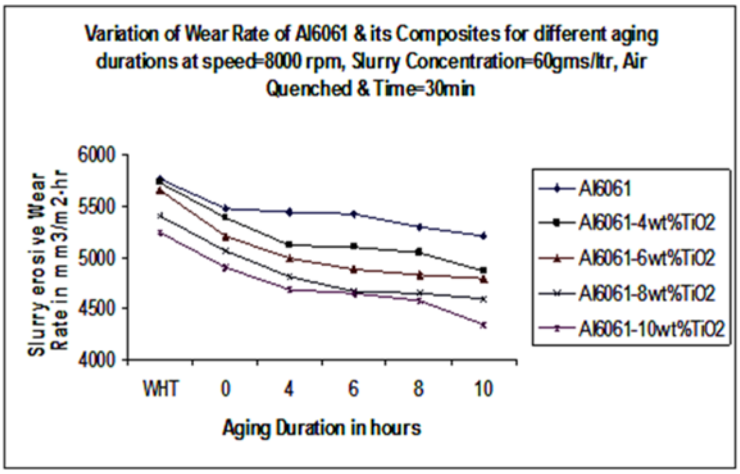
1. Al 6061-TiO_2 composites have been cast successfully by liquid metallurgy route.
2. Al 6061 alloy and Al 6061-TiO_2 composites have been successfully heat treated.
3. Micro structure clearly confirms minimum porosity in composites developed and formation of intermetallic precipitates.
4. Ice quenching have a profound influence on microhardness.
5. With increase in ageing duration up to 8 hrs there is an increase in microhardness for both Al 6061 alloy and Al 6061-TiO_2 composites.
6. Al 6061- TiO_2 composites possess superior slurry erosion resistance when compared with Al 6061 alloy.
7. There is a significant effect of quenching media on the slurry erosive wear of both the base matrix alloy and its composites. Ice quenched specimens have a profound effect on slurry erosive wear resistance when compared to water and air quenched specimens for all the test conditions.
8. Ageing duration has a profound effect on the slurry erosive wear resistance of both the base alloy and Al6061-TiO_2 composites. With an increase in ageing duration, there is an increase in slurry erosive wear resistance for all the quenching media studied.



(a) Ice Quenched



(b) Water Quenched



(c) Air Quenched

Figure 9. Variation of slurry erosive wear rate of cast Al6061 and cast Al6061-TiO_2 composites for different aging durations under identical test conditions.

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