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Investigation of Residual Stress, and Corrosion Behavior of AA6082/Al_2O_3/C/ Si_3N_4 Composite Material

Dhananjay Kumar[1], Yashpal[2], Ratnesh Kumar Sharma[3,*]

Abstract

The main objective of the current study was to create AA6082/ Al_2O_3/C/Si_3N_4 Composite Material by the use of stir casting. The properties of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material shown a significant improvement, with a micro-hardness rise of 13.5% and a residual stress decrease of 60%. As the testing parameters were increased, the residual stress of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material rapidly decreased from -65MPa to -15MPa. An electromagnetic stirrer was used in this study's stir casting process to create the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material. After using acetone to clean them, the AA6082 rods were divided into smaller pieces and heated to 850°C in an electric muffle furnace. The crucible was then used to melt the rods. The findings of the residual stress test showed a 60% decrease. The current discovery reported an increase in the hardness of the composite material AA6082/ Al_2O_3/C/ Si_3N_4 Composite. Experimental research has demonstrated that the development of nitrides and oxides in the manufactured composite leads to a decrease in residual stress. As the testing parameters were increased, the micro-hardness of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material rapidly increased from 210 HV to 260 HV. The corrosion test results also revealed a notable mass loss of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material sample, with decreases of approximately 55.2% after 1.5 hours, 43.1% after 2.5 hours, and 32% after 3.5 hours of exposure. Experimental research has demonstrated that the development of nitrides and oxides in the manufactured composite leads to a decrease in mass loss. When the generated composite solidifies, the increased dislocation density causes a decrease in grain size, which may be the cause of the increase in micro-hardness.

Keywords: Composite; corrosion test; AA6082/ Al_2O_3/C/ Si_3N_4; composite; residual stress

INTRODUCTION

IC engine tribological performance has recently increased thanks to advances in surface geometry optimisation, enhanced lubrication, and the incorporation of composite materials and speciality coatings. According to studies, the main techniques for improving the performance of piston components include surface topography [2–3]. surface modification [4–5]. MMC's [5–7]. and lubrication regime change [1]. Because sophisticated materials are in greater demand in modern engineering, metal matrix composites, or MMCs, are becoming more and more significant. In order to improve microstructural behaviour and attain particular mechanical properties, MMCs which are well-known for their exceptional qualities including high strength, stiffness, wear resistance, and damping capacity [6–7].

Because of their exceptional qualities, aluminum-based MMCs in particular are extensively utilised in the industrial sectors [7-8]. The properties of AMCs were investigated by Tyagi et al. [9]. who observed improved tensile strength. In their

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investigation of the COF and wear of SiC-reinforced composites, Mishra et al. [10]. discovered that wear rates and COF decrease with SiC increases, after which they start to rise again. Yadav et al. [11]. investigated an Al/SiC/Al2O3/fly ash composite in a different investigation and came to the conclusion that the fly ash improves the material's hardness and wear resistance [12]. Maleque et al.'s [13]. .additional research confirmed that the tribological characteristics of the composite material.

Improvements in lubricating methods, surface shape optimisation, and the use of non-traditional composite materials have all brought about notable progress in tribological performance. As vital engine parts, piston rings are responsible for 40–45% of the energy lost to friction. Exhaust emissions, power loss, and fuel economy are all directly impacted by the piston assembly's tribological efficiency. The literature states that surface modification, lubrication regimes, and surface topography optimisation are commonly employed to attain performance enhancements [14–17]. The two main techniques for lowering wear and friction are thought to be surface engineering and modification. Numerous surface modification methods have been developed by extensive research to improve performance of piston rings [18–21]. One of the most widely used techniques for creating composite coatings that improve the tribological, mechanical, and chemical characteristics of piston rings. The aim present study:

- Development of AA6082/Al2O3/C/ Si3N4 Composite Material
- Evaluation of residual stress, corrosion test and micro-hardness of AA6082/Al2O3/C/ Si3N4 Composite Material.

EXPERIMENTAL PROCEDURE

An electromagnetic stirrer was used in this study's stir casting process to create the *AA6082/* Al_2O_3/C/ Si_3N_4 Composite Material. After using acetone to clean them, the AA6082 rods were divided into smaller pieces and heated to 850°C in an electric muffle furnace. The crucible was then used to melt the rods. The crucible was regularly filled with argon gas to prevent contamination and guarantee the production of high-quality composite material. Preheated Al_2O_3/C/ Si_3N_4 Composite Material were added to the molten metal once the AA6082 had completely melted. Using a mechanical stirrer, the mixture of AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material was agitated for 15 minutes at 200 rpm. A Vickers hardness tester was used to determine the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material ' micro-hardness, and a stress analyser was used to evaluate any internal residual stresses. Using an electrochemical approach in an electrolytic solution, the mass loss of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material was calculated for the corrosion test.

EXPERIMENTAL RESULTS

Micro-Hardness

As the testing parameters were increased, the micro-hardness of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material rapidly increased from 210 HV to 260 HV, as shown in Figure 1. The findings of the micro hardness test showed a 13.5% improvement. The current discovery aligns with the study carried out by Tyagi et al. [23], which reported an increase in the hardness of the composite material AA6082/ Al_2O_3/C/ Si_3N_4 Composite. Experimental research has demonstrated that the development of nitrides and oxides in the manufactured composite leads to an increase in micro-hardness. When the generated composite solidifies, the increased dislocation density causes a decrease in grain size, which may be the cause of the increase in micro-hardness [22-28].

Residual Stress

As the testing parameters were increased, the residual stress of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material rapidly decreased from -65MPa to -15MPa, as shown in Figure 2. The findings of the residual stress test showed a 60% decrease. The current discovery aligns with the study carried out by Tyagi et al. [23], which reported an increase in the hardness of the composite material AA6082/ Al_2O_3/C/ Si_3N_4 Composite. Experimental research has demonstrated that the development of nitrides and oxides in the manufactured composite leads to a decrease in residual stress. When the generated composite solidifies, the increased dislocation density causes a decrease in grain size, which may be the cause of the decrease in residual stress [22-28]. The distribution using different colour combinations shows residual stress concentrations is depicted in Figure 3.

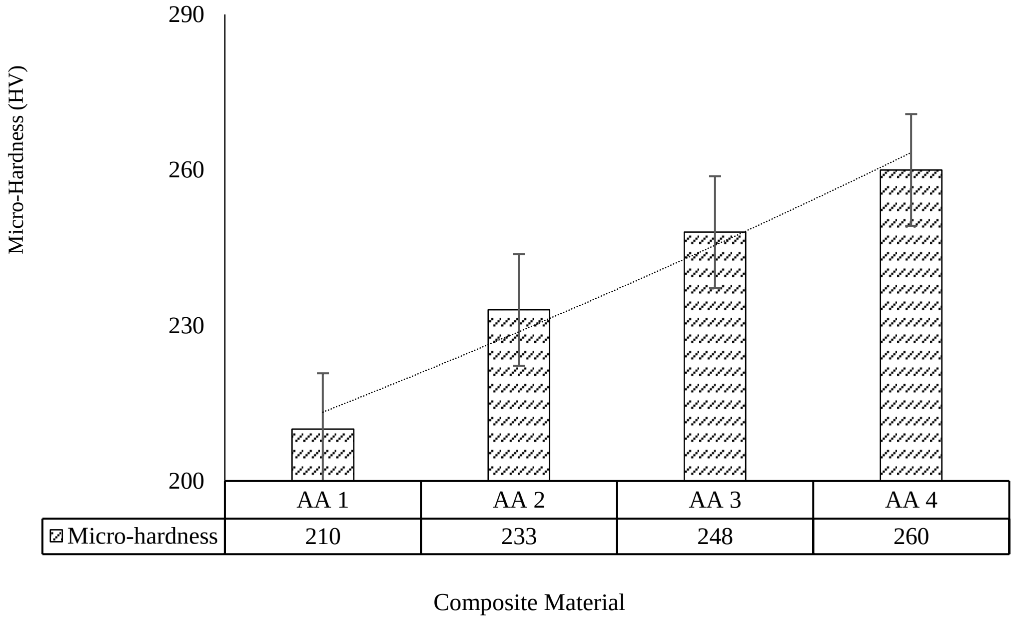

Figure 1. Micro-hardness Vs composite material.

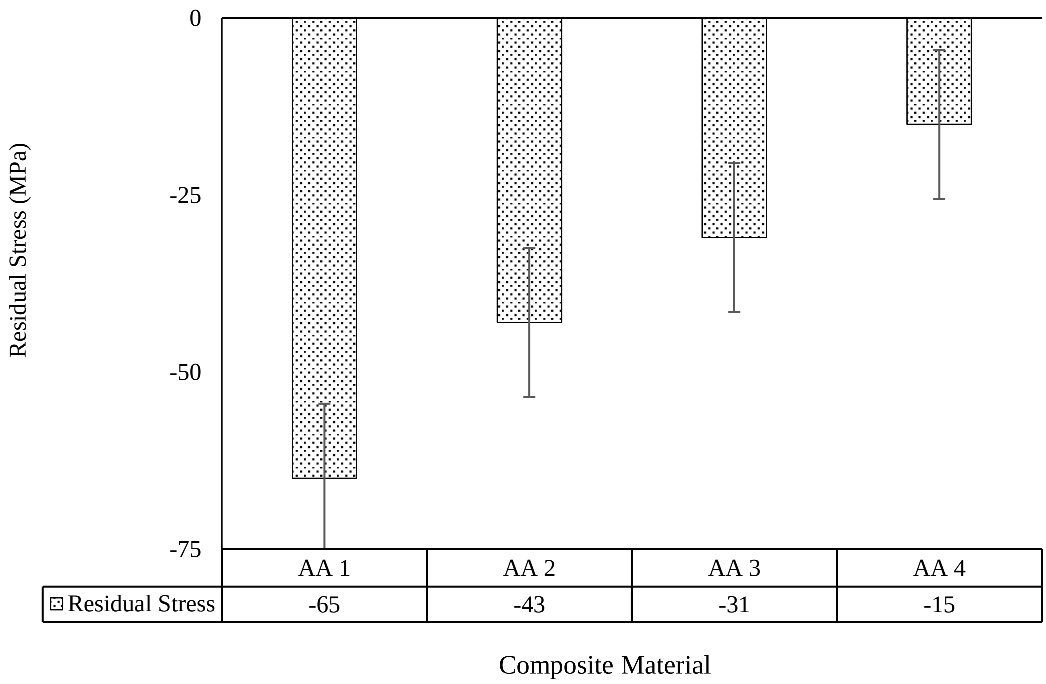

Figure 2. Residual stress Vs composite Material

Corrosion Test

As the testing parameters were increased, the mass loss during corrosion test of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material rapidly decreased from 435 to 270 mg/mm2, as shown in Figure 4. The corrosion test results also revealed a notable mass loss of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material sample, with decreases of approximately 55.2% after 1.5 hours, 43.1% after 2.5 hours, and 32% after 3.5 hours of exposure. Experimental research has demonstrated that the development of nitrides and oxides in the manufactured composite leads to an decrease in mass loss. When the generated composite solidifies, the increased dislocation density causes a decrease in grain size, which may be the cause of the decrease in mass loss [22-28].

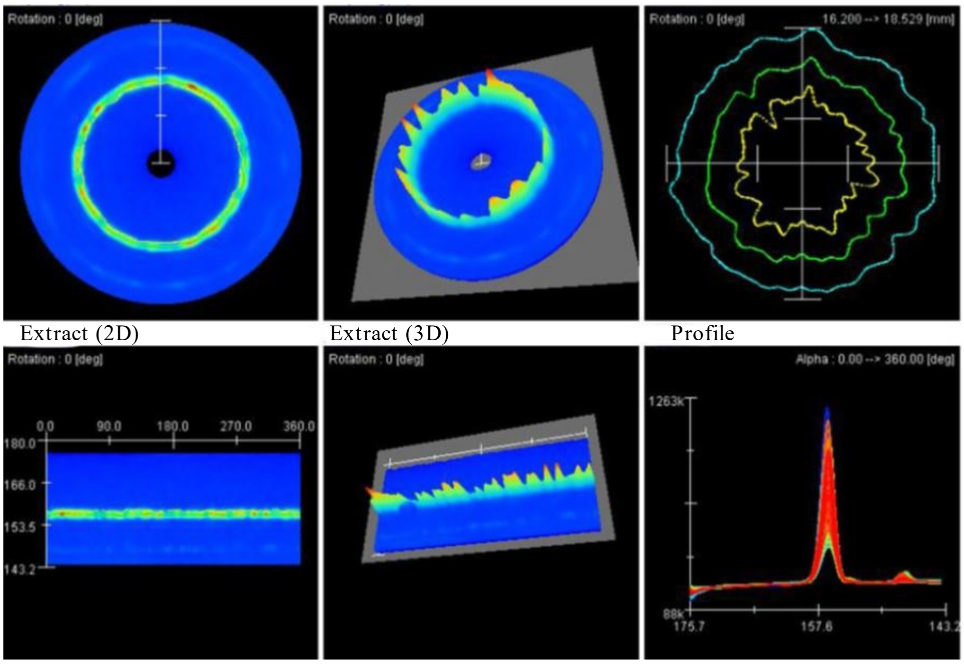

Figure 3. Residual stress distribution.

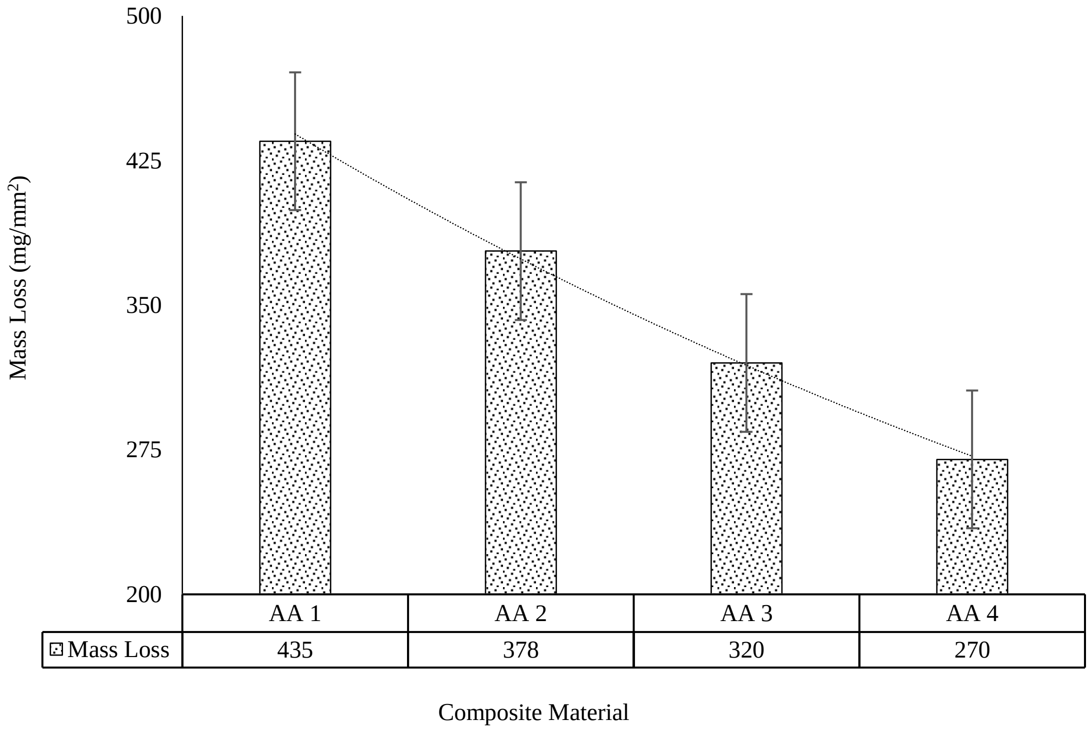

Figure 4. Corrosion test result

CONCLUSIONS

The present study's primary goal was to develop AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material using stir casting process. The properties of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material shown a significant improvement, with a micro-hardness rise of 13.5% and a residual stress decrease of 60%. The corrosion test results also revealed a notable mass loss of the AA6082/ Al_2O_3/C/ Si_3N_4 Composite Material sample, with decreases of approximately 55.2% after 1.5 hours, 43.1% after 2.5 hours, and 32% after 3.5 hours of exposure.

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