Sliding Wear Behavior of Boron Nitride Reinforced AA6061 Metal Matrix Composites

K. Narayan Naik
PG Student, Department of Mechanical Engineering, JNT University, Hyderabad

Under the Guidance of Dr. A. Chennakesava Reddy, Associate Professor, JNTUH College of Engineering, JNT University, Hyderabad.

ABSTRACT

In the past few years, the demand for lighter weight materials with increased specific strength for the automotive and aerospace industries has caused the development and usage of aluminum alloy based composites. Aluminum metal matrix composites reinforced with ceramic particles are gaining wide popularity as high performance material because of their improved strength, high elastic modulus and increased wear resistance, their ability to exhibit superior strength-to-weight and strength-to-cost ratio over conventional base alloy. Al alloy based metal matrix composites are presently used in several applications such as pistons, pushrods, cylinder liners and brake discs. Metal composite self-lubricating composites are among the materials that are currently of great scientific interest. Self-lubricating composites have also been developed for engineering applications, including gears, bearings, bushings and cams. Erosive and abrasive wear may both be viewed as surface damage resulting from the relative motion with another body. Where the two forms of wear diverge involves the nature of the relative motion. Numerous reports are available on the subject of the fabrication and wear studies of the metal matrix composites. Ceramic materials TiO_2, graphite, carbon, ZrO_2, TiN, B4C, ZrC, Si_3N_4 and SiO_2 provide wear resistance and mechanical strength.

The aim of this project work was to model the effect of boron nitride (BN) particle size on the sliding wear of AA6061-BN composites. For this purpose AA6061-BN metal matrix composites were manufactured with particle size varying from 100μm to 200μm. Dry sliding wear of AA6061 alloy-BN composites with different particle sizes were studied under different combinations of sliding speed, normal load, sliding distance and particle size based on Taguchi techniques.

The impact of micro-size particles on the severity of wear was modeled and validated with experimental results of AA6061 alloy-BN composites. The ploughing of particles due to wear and hard asperities were observed on the surfaces of 200μm particle reinforced composites.

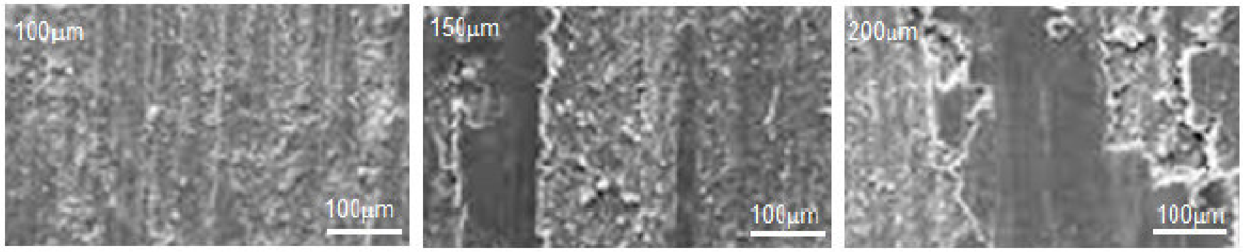

Figure 1: Micrographs of worn surfaces.

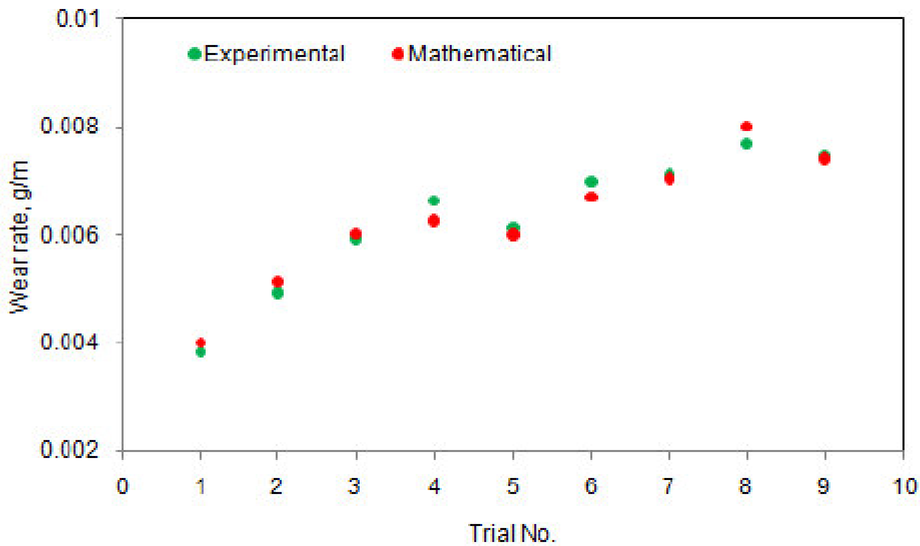

Figure 2: Validation of mathematical modeling with experimental results.

References:

1. A. C. Reddy, Effect of Particle Loading on Microealstic Behavior and interfacial Tractions of Boron Carbide/AA4015 Alloy Metal Matrix Composites, 1st International Conference on Composite Materials and Characterization, Bangalore, 14-15 March 1997, pp.176-179.
2. A. C. Reddy, Reckoning of Micro-stresses and interfacial Tractions in Titanium Boride/AA2024 Alloy Metal Matrix Composites, 1st International Conference on Composite Materials and Characterization, Bangalore, 14-15 March 1997, pp.195-197.
3. A. C. Reddy, Interfacial Debonding Analysis in Terms of Interfacial Tractions for Titanium Boride/AA3003 Alloy Metal Matrix Composites, 1st National Conference on Modern Materials and Manufacturing, Pune, India, 19-20 December 1997, pp.124-127.
4. A. C. Reddy, Evaluation of Debonding and Dislocation Occurrences in Rhombus Silicon Nitride Particulate/AA4015 Alloy Metal Matrix Composites, 1st National Conference on Modern Materials and Manufacturing, Pune, India, 19-20 December 1997, pp.278-282.
5. A. C. Reddy, Assessment of Debonding and Particulate Fracture Occurrences in Circular Silicon Nitride Particulate/AA5050 Alloy Metal Matrix Composites, National Conference on Materials and Manufacturing Processes, Hyderabad, India, 27-28 February 1998, pp.104-109.
6. A. C. Reddy, Local Stress Differential for Particulate Fracture in AA2024/Titanium Carbide Nanoparticulate Metal Matrix Composites, National Conference on Materials and Manufacturing Processes, Hyderabad, India, 27-28 February 1998, pp.127-131.

7. A. C. Reddy, Cohesive Zone Finite Element Analysis to Envisage Interface Debonding in AA7020/Titanium Oxide Nanoparticulate Metal Matrix Composites, 2nd International Conference on Composite Materials and Characterization, Nagpur, India, 9-10 April 1999, pp.204-209.
8. A. C. Reddy, Micromechanical Modelling of Interfacial Debonding in AA1100/Graphite Nanoparticulate Reinforced Metal Matrix Composites, 2nd International Conference on Composite Materials and Characterization, Nagpur, India, 9-10 April 1999, pp.249-253.
9. A. C. Reddy, Micromechanical and fracture behaviors of Ellipsoidal Graphite Reinforced AA2024 Alloy Matrix Composites, 2nd National Conference on Materials and Manufacturing Processes, Hyderabad, India, 10-11 March 2000, pp.96-103.
10. A. C. Reddy, Constitutive Behavior of AA5050/MgO Metal Matrix Composites with Interface Debonding: the Finite Element Method for Uniaxial Tension, 2nd National Conference on Materials and Manufacturing Processes, Hyderabad, India, 10-11 March 2000, pp.121-127.
11. A. C. Reddy, Effect of CTE and Stiffness Mismatches on Interphase and Particle Fractures of Zirconium Carbide/AA5050 Alloy Particle-Reinforced Composites, 3rd International Conference on Composite Materials and Characterization, Chennai, India, 11-12 May 2001, pp.257-262.
12. A. C. Reddy, Behavioral Characteristics of Graphite /AA6061 Alloy Particle-Reinforced Metal Matrix Composites, 3rd International Conference on Composite Materials and Characterization, Chennai, India, 11-12 May 2001, pp.263-269.
13. A. C. Reddy, Prediction of CTE of Al/TiB2 Metal Matrix Composites, 3rd International Conference on Composite Materials and Characterization, Chennai, India, 11-12 May 2001, pp.270-275.
14. A. C. Reddy, Significance of Testing Parameters on the Wear Behavior of AA1100/B4C Metal Matrix Composites based on the Taguchi Method, 3rd International Conference on Composite Materials and Characterization, Chennai, India, 11-12 May 2001, pp.276-280.
15. A. C. Reddy, Mechanisms of Load Transfer in Tension to Estimate Interfacial Behaviour of Kevlar 29 / Epoxy Composites by Laser Raman Spectroscopy, National Conference on Advances in Manufacturing Technologies (AMT-2001), Pune, 9-10 March 2001, pp.205-207.
16. A. C. Reddy, Fracture behavior of brittle matrix and alumina trihydrate particulate composites, Indian Journal of Engineering & Materials Sciences, vol. 9, no. 5, pp. 365-368, 2002.
17. A. C. Reddy, Two dimensional (2D) RVE-Based Modeling of Interphase Separation and Particle Fracture in Graphite/5050 Particle Reinforced Composites, 3rd National Conference on Materials and Manufacturing Processes, Hyderabad, India, 22-25 February 2002, pp.179-183.
18. A. C. Reddy, Simulation of MgO/AA6061 Particulate-Reinforced Composites Taking Account of CTE Mismatch Effects and Interphase Separation, 3rd National Conference on Materials and Manufacturing Processes, Hyderabad, India, 22-25 February 2002, pp.184-187.
19. A. C. Reddy, Evaluation of Thermal Expansion of Al/B4C Metal Matrix Composites, 3rd National Conference on Materials and Manufacturing Processes, Hyderabad, India, 22-25 February 2002, pp.196-200.
20. A. C. Reddy, Wear Resistant Titanium Boride Metal Matrix Composites, 3rd National Conference on Materials and Manufacturing Processes, Hyderabad, India, 22-25 February 2002, pp.201-205.

21. A. C. Reddy, Finite Element Analysis Study of Micromechanical Clustering Characteristics of Graphite/AA7020 Alloy Particle Reinforced Composites, 4th International Conference on Composite Materials and Characterization, Hyderabad, India, 7-8 March 2003, pp.206-210.
22. A. C. Reddy, Investigation of the Clustering Behavior of Titanium Diboride Particles in TiB2/AA2024 Alloy Metal Matrix Composites, 4th International Conference on Composite Materials and Characterization, Hyderabad, India, 7-8 March 2003, pp.216-220.
23. A. C. Reddy, Thermal Expansion Studies on Aluminum Matrix Composites with Different Reinforcement Volume Fractions of Si3N4 Nanoparticles, 4th International Conference on Composite Materials and Characterization, Hyderabad, India, 7-8 March 2003, pp.221-225.
24. A. C. Reddy, On the Wear of AA4015 – Fused Silica Metal Matrix Composites, 4th International Conference on Composite Materials and Characterization, Hyderabad, India, 7-8 March 2003, pp.226-230.
25. A. C. Reddy, B. Kotiveerachari, Effect of matrix microstucture and reinforcement fracture on the properties of tempered SiC/Al-alloy composites, National conference on advances in materials and their processing, Bagalkot, 28-29th November 2003, pp.121-124.
26. A. C. Reddy, Finite element analysis of elastic-plastic and tensile damage response in carbon-carbon composites under vechicular crush conditions, National Conference on Emerging Trends in Mechanical Engineering, Nagapur, 05-06th February 2004.
27. A.C. Reddy, Experimental evaluation of elastic lattice strains in the discontinuously SiC reinforced Al-alloy composites, National Conference on Emerging Trends in Mechanical Engineering, Nagapur, 05-06th February 2004.
28. A. C. Reddy, Thermal Expansion Behavior of Aluminum Matrix Composites Reinforced with Fused Quartz Nanoparticles, National Conference on Advanced Materials and Manufacturing Techniques, Hyderabad, 08-09th March 2004, pp. 350-355.
29. A. C. Reddy, Wear Characteristics of AA5050/TiC Metal Matrix Composites, National Conference on Advanced Materials and Manufacturing Techniques, Hyderabad, 08-09th March 2004, 356-360.
30. A. C. Reddy, Analysis of the Relationship Between the Interface Structure and the Strength of Carbon-Aluminum Composites, NATCON-ME, Bangalore, 13-14th March, 2004, 61-62.
31. A. C. Reddy, S. Sundararajan, Influences of ageing, inclusions and voids on the ductile fracture mechanism of commercial Al-alloys, Journal of Bulletin of Material Sciences, vol. 28, no. 1, pp. 101-105, 2005.
32. A. C. Reddy, Effect of Porosity Formation during Synthesis of Cast AA4015/Titanium Nitride Particle-Metal Matrix Composites, 5th National Conference on Materials and Manufacturing Processes, Hyderabad, 9-10 June 2006, 139-143.
33. A. C. Reddy, Stir Casting Process on Porosity Development and Micromechanical Properties of AA5050/Titanium Oxide Metal Matrix Composites, 5th National Conference on Materials and Manufacturing Processes, Hyderabad, 9-10 June 2006, 144-148.
34. A. C. Reddy, Effect of TiC Nanoparticles on the Coefficient of Thermal Expansion Behavior of the Aluminum Metal Matrix Composites, 5th National Conference on Materials and Manufacturing Processes, Hyderabad, 9-10 June 2006, 164-168.
35. A. C. Reddy, Tribological Behavior of AA8090/MgO Composites, 5th National Conference on Materials and Manufacturing Processes, Hyderabad, 9-10 June 2006, 169-173.
36. A. C. Reddy, Effect of Clustering Induced Porosity on Micromechanical Properties of AA6061/Titanium Oxide Particulate Metal Matrix Composites, 6th International Conference on Composite Materials and Characterization, Hyderabad, 8-9 June 2007, 149-154, 2007.

37. A. C. Reddy, Mechanical properties and fracture behavior of 6061/SICp Metal Matrix Composites Fabricated by Low Pressure Die Casting Process, Journal of Manufacturing Technology Research, vol. 1, no. 3/4, pp. 273-286, 2009.
38. A. C. Reddy, Essa Zitoun, Matrix Al-alloys for alumina particle reinforced metal matrix composites, Indian Foundry Journal, vol. 55, no. 1, pp. 12-16, 2009.
39. A. C. Reddy, Wear and Mechanical Behavior of Bottom-Up Poured AA4015/Graphite Particle-Reinforced Metal Matrix Composites, 6th National Conference on Materials and Manufacturing Processes, Hyderabad, 8-9 August 2008, pp. 120-126.
40. A. C. Reddy, B. Kotiveerachari, Effect of aging condition on structure and the properties of Al-alloy/SiC composite, International Journal of Engineering and Technology, vol. 2, no. 6, pp. 462-465, 2010.
41. A. C. Reddy, Tensile properties and fracture behavior of 6063/SiC_P metal matrix composites fabricated by investment casting process, International Journal of Mechanical Engineering and Materials Sciences, vol. 3, no. 1, pp. 73-78, 2010.
42. A. C. Reddy, M. Vidya Sagar, Two-dimensional theoretical modeling of anisotropic wear in carbon/epoxy FRP composites: comparison with experimental data, International Journal of Theoretical and Applied Mechanics, vol. 6, no. 1, p. 47-57, 2010.
43. A. C. Reddy, Essa Zitoun, Tensile behavior of 6063/Al2O3 particulate metal matrix composites fabricated by investment casting process, International Journal of Applied Engineering Research, vol. 1, no. 3, pp. 542-552, 2010.
44. A. C. Reddy, Essa Zitoun , Matrix Al-alloys for silicon carbide particle reinforced metal matrix composites, Indian journal of Science and Technology, vol. 3, no. 12, pp. 1184-1187, 2010.
45. A. C. Reddy, Sliding Wear and Micromechanical Behavior of AA1100/Titanium Oxide Metal Matrix Composites Cast by Bottom-Up Pouring, 7th International Conference on Composite Materials and Characterization, Bangalore, 11-12 December 2009, pp. 205-210.
46. A. C. Reddy, Hardness Contours and Worn Surfaces of AA1100 Alloy/TiO2 Metal Matrix Composites, 2nd International Conference on Modern Materials and Manufacturing, Pune, 10-11 December 2010, pp. 292-296.
47. A. C. Reddy, Correlation of Surface Profiles and Worn Surfaces of AA6061/Graphite Metal Matrix Composites, 2nd International Conference on Modern Materials and Manufacturing, Pune, 10-11 December 2010, pp. 307-311.
48. A. C. Reddy, Essa Zitoun, Tensile properties and fracture behavior of 6061/Al_2O_3 metal matrix composites fabricated by low pressure die casting process, International Journal of Materials Sciences, vol. 6, no. 2, pp. 147-157, 2011.
49. A. C. Reddy, Influence of strain rate and temperature on superplastic behavior of sinter forged Al6061/SiC metal matrix composites, International Journal of Engineering Research & Technology, vol. 4, no. 2, pp. 189-198, 2011.
50. A. C. Reddy, Strengthening mechanisms and fracture behavior of 7072Al/Al_2O_3 metal matrix composites, International Journal of Engineering Science and Technology, vol. 3, no. 7, pp. 6090-6100, 2011.
51. A. C. Reddy, Evaluation of mechanical behavior of Al-alloy/Al_2O_3 metal matrix composites with respect to their constituents using Taguchi, International Journal of Emerging Technologies and Applications in Engineering Technology and Sciences, vol. 4, no. 2, pp. 26-30, 2011.
52. A. C. Reddy, Tensile fracture behavior of 7072/SiCp metal matrix composites fabricated by gravity die casting process, Materials Technology: Advanced Performance Materials, vol. 26, no. 5, pp. 257-262, 2011.
53. A. C. Reddy, Evaluation of mechanical behavior of Al-alloy/SiC metal matrix composites with respect to their constituents using Taguchi techniques, i-manager's Journal of Mechanical Engineering, vol. 1, no. 2, pp. 31-41, 2011.
54. A. C. Reddy, B. Kotiveerachari, Influence of microstructural changes caused by ageing on wear behaviour of Al6061/SiC composites, Journal of Metallurgy & Materials Science, vol. 53, no. 1, pp. 31-39, 2011.

55. A. C. Reddy, Experimental Validation of Dry Wear Formulation of AA7020/Zirconia Nanoparticle Metal Matrix Composites, 3rd International Conference on Modern Materials and Manufacturing, New Delhi, 9-10 December 2011, pp. 357-361.
56. A. C. Reddy, Impact of Particle Size on Dry Wear Formulation of AA2024/Titanium Nitride Macro-Particle Metal Matrix Composites, 3rd International Conference on Modern Materials and Manufacturing, New Delhi, 9-10 December 2011, pp. 362-366.
57. M. Mastanaih, A. C. Reddy, Exploitation of Reinforcement in Revision of Wear Behavior of AA1100/Si3N4 Metal Matrix Composites, 5th International Conference on Modern Materials and Manufacturing, Bangalore, 6-7 December 2013, pp. 379-383.
58. V. K. Reddy, A. Chennakesava Reddy, Wear performance of AA4015/Boron Carbide Metal Matrix Composites, 5th International Conference on Modern Materials and Manufacturing, Bangalore, 6-7 December 2013, pp. 384-388.
59. M. Mastanaih, A. C. Reddy, Influence of Reinforcing Particle Size on Tribological Properties of AA6061-Titanium Carbide Microcomposites, 5th International Conference on Modern Materials and Manufacturing, Bangalore, 6-7 December 2013, pp. 389-393.
60. V. K. Reddy, A. C. Reddy, Role of Reinforcing Particle Size in the Wear Behavior of AA6061-Titanium Nitride Composites, 5th International Conference on Modern Materials and Manufacturing, Bangalore, 6-7 December 2013, pp. 394-398.
61. V. B. Reddy, A. C. Reddy, Sliding Wear by Hard and Micro-Particles of AA2024-Zirconium Carbide Metal Matrix Composites, 5th International Conference on Modern Materials and Manufacturing, Bangalore, 6-7 December 2013, pp. 399-403.
62. T. K. K. Reddy, A. C. Reddy, Wear Performance of Magnesia as Reinforcement of AA2024 Metal Matrix Composites, 5th International Conference on Modern Materials and Manufacturing, Bangalore, 6-7 December 2013, pp. 404-408.
63. A. C. Reddy, Study of Factors Influencing Sliding Wear Behavior of Hexagonal Boron Nitride Reinforced AA6061 Metal Matrix Composites, 5th International Conference on Modern Materials and Manufacturing, Bangalore, 6-7 December 2013, pp. 409-413.
64. A. C. Reddy, Thermal Expansion of Al Matrix Composites Reinforced with TiN Nanoparticles, 2nd International Conference on Thermal and Tribological Behavior of Composites, New Delhi, 27-28 December 2013, pp. 144-148.
65. T. K. K. Reddy, A. C. Reddy, Tribological Behavior of AA8090/SiC Composites, 2nd International Conference on Thermal and Tribological Behavior of Composites, New Delhi, 27-28 December 2013, pp. 149-154.
66. A. C. Reddy, Tribological Behavior of Nano Titanium Carbide Particles Embedded in 8090 AL alloy Metal Matrix Composites, 2nd International Conference on Thermal and Tribological Behavior of Composites, New Delhi, 27-28 December 2013, pp. 155-160.