

LIST OF FIGURES

Figure No.	Figure Caption	Page No.
Figure 1.1	Schematic diagram of (a) particulate reinforced composite, (b) continuous fiber reinforced composite, (c) short fiber or whisker reinforced composite, and (d) woven or braided. composite	3
Figure 1.2	Schematic diagram of experimental set-up for composite fabrication by RSC process.	7
Figure 1.3	Schematic diagram of the composite fabrication by XD process.	8
Figure 1.4	Schematic diagram of apparatus used in DMR technique.	9
Figure 1.5	Variation in wear rate with sliding distance.	14
Figure 1.6	Schematic diagram of the two metallic surfaces in contact (a) hard on soft, (b) hard on hard and (c) hard on hard with thin film of soft metal.	17
Figure 1.7	Variation in coefficient of friction with sliding distance.	18
Figure 2.1	(a) electric oven used to dehydrate inorganic salts and (b) stir-casting unit with bottom pouring arrangement.	32
Figure 2.2	As cast composite ingot.	32
Figure 2.3	XRD machine for XRD analysis of composites.	33
Figure 2.4	(a) Optical emission spectrometer for chemical composition analysis of composites, and (b) composite sample after test.	34
Figure 2.5	DTA/TGA machine for DTA analysis of composite.	35
Figure 2.6	Optical microscope.	37
Figure 2.7	Scanning-electron microscope.	38
Figure 2.8	(a) Transmission-electron microscope and (b) twin-jet electro-polishing machine.	38
Figure 2.9	(a) Brinell hardness tester and (b) Vickers micro-hardness tester.	39
Figure 2.10	(a) Tensile testing machine, and (b) schematic representation of tensile specimen.	40
Figure 2.11	Pin on disc configuration of a multi-function tribometer.	42
Figure 2.12	(a) High temperature wear testing machine, (b) sample holder with sample, and (c) EN31 disc.	43
Figure 2.13	3D-Profilometer.	44
Figure 3.1	XRD pattern of Al-Mg alloy and composites.	49
Figure 3.2	DTA curve of Al ₃ Zr/Al-Mg composite.	49
Figure 3.3	SEM micrograph of extracted particles.	50
Figure 3.4	XRD pattern of extracted particles from Al ₃ Zr/Al-Mg composite.	50
Figure 3.5	Optical micrographs of (a) Al-Mg alloy, and composites with (b) 10 vol.% Al ₃ Zr, (c) 12.5 vol.% Al ₃ Zr, (d) 15 vol.% Al ₃ Zr, (e) 20 vol.% Al ₃ Zr, and (f) 30 vol.% Al ₃ Zr.	52

Figure 3.6	Scanning electron micrographs of composites with different vol.% of Al ₃ Zr particles (a) 10 vol.% Al ₃ Zr, (b) 12.5 vol.% Al ₃ Zr, (c) 15 vol.% Al ₃ Zr, (d) 20 vol.% Al ₃ Zr, and (e) 30 vol.% Al ₃ Zr.	54
Figure 3.7	Scanning electron micrographs of (a) rectangular Al ₃ Zr, (b) polyhedron Al ₃ Zr, and (c) EDS of the Al ₃ Zr.	55
Figure 3.8	Histogram showing of particle size distribution of Al ₃ Zr particles in composites.	55
Figure 3.9	TEM Micrographs of Al ₃ Zr/Al-Mg composite: (a) showing the rod like Al ₃ Zr particle, (b) SAD pattern of the rod like Al ₃ Zr, (c) SAD pattern of matrix, and (d) dislocation near rod like Al ₃ Zr particle.	56
Figure 3.10	Engineering stress-strain curves of the Al-Mg alloy and composites.	58
Figure 3.11	Variation of mechanical properties in composites.	59
Figure 3.12	Fractographs of (a) Al-Mg alloy, and composites with (b) 10 vol.% Al ₃ Zr, (c) 12.5 vol.% Al ₃ Zr, (d) 15 vol.% Al ₃ Zr, (e) 20 vol.% Al ₃ Zr, (f) 30 vol.% Al ₃ Zr.	60
Figure 3.13	(a) Variation of cumulative mass loss with sliding distance, and (b) coefficient of friction with sliding distance.	62
Figure 3.14	(a) Variation of wear rate with normal load, (b) wear rate/ vol.% Al ₃ Zr with normal load, and (c) coefficient of friction with normal load.	63
Figure 3.15	(a) Variation of wear rate with sliding velocity, (b) wear coefficient with sliding velocity, and (c) coefficient of friction with sliding velocity.	65
Figure 3.16	(a) Variation of wear rate with vol.% of Al ₃ Zr, (b) normalized wear rate with vol.% of Al ₃ Zr, (c) wear coefficient with vol.% of Al ₃ Zr; and (d) coefficient of friction with vol.% of Al ₃ Zr.	66
Figure 3.17	Line analysis and its 3D-profilometry images for composite before wear test.	67
Figure 3.18	Line analysis and 3D-profilometry images for composite with 10 vol.% Al ₃ Zr at 10 N normal load and 1 m/s sliding velocity for a sliding distance of (a) 600 m and (b) 3000 m.	68
Figure 3.19	SEM micrographs and corresponding EDS of the wear track with the presence of debris particles in composite with 10 vol.% Al ₃ Zr at 1 m/s sliding velocity and load of (a) 20 N, and (b) 40 N.	69
Figure 3.20	Line analysis and 3D-profilometry images for composite with 30 vol.% Al ₃ Zr at 1 m/s sliding velocity and normal load of (a) 30 N, and (b) 40 N.	71
Figure 3.21	The SEM micrographs of wear track for composite with 10 vol.% Al ₃ Zr at 20 N normal load and sliding speed of (a) 1 m/s, and (b) 4 m/s.	72
Figure 3.22	The SEM micrographs and their corresponding EDS pattern of wear track for composite with 10 vol.% Al ₃ Zr at 20 N normal load and sliding speed of (a) 2 m/s, and (b) 4 m/s.	72
Figure 3.23	Line analysis and 3D-profilometer images for composite with 10 vol.% Al ₃ Zr at 20 N load and sliding velocity of (a) 2 m/s, and (b) 4 m/s.	74

Figure 3.24	Line analysis and 3D-profilometer images for composite with 30 vol.% Al ₃ Zr at 20 N load and sliding velocity of (a) 2 m/s, and (b) 4 m/s.	76
Figure 3.25	Line analysis and 3D-profilometer images at 20 N load and 1 m/s sliding velocity for (a) Al-Mg alloy, (b) composite with 10 vol.% Al ₃ Zr, and (c) composite with 30 vol.% Al ₃ Zr.	77
Figure 4.1	XRD pattern of Al-Mg alloy and composites.	84
Figure 4.2	XRD pattern of extracted particles from (ZrB ₂ +Al ₃ Zr)/Al-Mg composite.	85
Figure 4.3	Optical micrographs of (a) C1, (b) C2, (c) C3 and (d) C4 composites.	88
Figure 4.4	Grain size distribution in (a) C1, (b) C2, (c) C3 and (d) C4 composites.	88
Figure 4.5	Scanning electron micrographs of hybrid composites with different vol.% of ZrB ₂ particles (a) C1, (b) C2, (c) C3, (d) C4, (e) & (f) clusters of ZrB ₂ particles at higher magnification.	89
Figure 4.6	(a) EDS pattern of cluster of ZrB ₂ particles, (b) EDS pattern of Al ₃ Zr particle, (c) hexagonal ZrB ₂ particles, and (d) rectangular ZrB ₂ particles.	90
Figure 4.7	Particle size histogram of (a) Al ₃ Zr in Al ₃ Zr/Al-Mg composite, (b) Al ₃ Zr in ((ZrB ₂ +Al ₃ Zr)/Al-Mg composites, and (c) ZrB ₂ in ((ZrB ₂ +Al ₃ Zr)/Al-Mg composites.	91
Figure 4.8	TEM Micrographs of hybrid composite: (a) rectangular and hexagonal ZrB ₂ particles, (b) dislocation free region near ZrB ₂ particle, (c), diffraction patterns of ZrB ₂ particles and (d) diffraction pattern of matrix.	92
Figure 4.9	TEM Micrographs of hybrid <i>insitu</i> composite (a) rectangular Al ₃ Zr particle and (b) diffraction pattern of Al ₃ Zr particle.	93
Figure 4.10	TEM Micrographs showing the dislocation in the matrix of hybrid composite.	93
Figure 4.11	Engineering stress-strain curves of the composites.	94
Figure 4.12	Variation of mechanical properties in composites.	95
Figure 4.13	σ vs. ϵ_p plots on log scale of composites.	97
Figure 4.14	Variation of flow curve properties of composites.	98
Figure 4.15	Fractographs of (a) C1, (b) C2, (c) C4, (d) and (e) show the debonding of ZrB ₂ clusters in C4 composite.	99
Figure 4.16	Contribution of different strengthening mechanisms in hybrid composites and comparison of predicted yield strength with experimental yield strength.	106
Figure 4.17	Variation of (a) cumulative mass loss and (b) coefficient of friction with sliding distance.	108
Figure 4.18	Variation of (a) Wear rate, (b) wear per unit vol.% reinforcement, and (c) coefficient of friction with different normal load.	109
Figure 4.19	Variation of (a) Wear rate, (b) wear coefficient, and (c) coefficient of friction with sliding speed.	111
Figure 4.20	Variation of (a) Wear rate, (b) normalized wear rate, (c) wear coefficient, and (d) coefficient of friction with different compositions.	112
Figure 4.21	Height analysis perpendicular to worn surface and its 3D-	114

	images for C4 composite at 1 m/s sliding velocity with different load at (a) 30 N, and (b) 40 N.	
Figure 4.22	Height analysis perpendicular to worn surface and its 3D-images for C4 composite at 20 N normal load for different sliding velocities of (a) 2 m/s, and (b) 4 m/s.	116
Figure 4.23	Height analysis perpendicular to worn surface and its 3D-image at 1 m/s sliding velocity and 20 N normal loads for (a) C1, (b) C2, and (c) C3 composite.	117
Figure 5.1	Engineering stress-strain curves of the Al-Mg alloy and hybrid composite at different temperatures.	122
Figure 5.2	Variation of mechanical properties in composite with temperatures.	123
Figure 5.3	σ vs. ϵ_p plots of hybrid composite with temperatures on log-log scale.	124
Figure 5.4	Variation of flow curve properties in composites with temperatures.	125
Figure 5.5	Scanning electron microstructures of tensile fracture surface of composite at different temperatures (a) room temperature, (b) 100 C and (c) 250°C.	126
Figure 5.6	Effect of temperature on (a) wear rate, and (b) coefficient of friction at constant sliding distance, sliding velocity and load.	127
Figure 5.7	Effect of normal load on (a) wear rate, and (b) coefficient of friction at constant sliding distance, sliding velocity and temperature.	128
Figure 5.8	Effect of composition on (a) wear rate, and (b) coefficient of friction with constant sliding distance, speed and normal load at different temperatures.	129
Figure 5.9	Scanning electron microstructures of worn surfaces of hybrid composite at constant sliding speed 0.5 m/s and normal load of 40 N for different temperatures (a) 100°C, (b) 150°C, (c) 200°C, and (d) 250°C.	131
Figure 5.10	Scanning electron microstructure of wear debris in hybrid composite at 250°C.	132
Figure 5.11	Height analysis perpendicular to worn surface and its 3D-profilometric images with the value of surface roughness at constant sliding speed 0.5 m/s and the normal load of 40 N at different temperature (a) 100°C, and (b) 250°C.	132
Figure 5.12	Scanning electron microstructures of worn surfaces of hybrid composite at constant sliding speed 0.5 m/s and temperature of 200°C for different normal load (a) 20 N, and (b) 40 N.	133
Figure 5.13	Height analysis perpendicular to worn surface and their 3D-profilometric images with the surface roughness value at constant sliding speed 0.5 m/s and temperature 200°C for different normal loads (a) 20 N, and (b) 40 N.	134
Figure 5.14	Height analysis perpendicular to worn surface and its 3D-profilometric images with the value of surface roughness at constant sliding speed 0.5 m/s and temperature 150°C of (a) Al-Mg alloy, and (b) hybrid composite.	135