LIST OF FIGURES

Figure 1.1 Schematic of friction stir processing process
Figure 2.1 Classification of FSP variables involved in SC fabrication
Figure 2.2 Schematic of tool geometry of FSP tool
Figure 2.3 Schematic of different pin profiles used in FSW/P20
Figure 2.4 Pinning effect: (a) nucleation of new grains at grain boundaries; (b)
Blocking of the grain growth by reinforcement particles in MMCs after
recrystallization25
Figure 2.5 Classification of reinforcement strategies
Figure 2.6 Steps in SC fabrication using the groove technique
Figure 2.7 Schematic view of: (a) groove covered with thin cover plate (b) drilled
hole pattern and (c) introduction of reinforcements via a hollow tool32
Figure 3.1 Optical micrograph of commercially pure copper
Figure 3.2 SEM micrograph of the particulates and particle size distribution (a) and
(b) zircon sand, (c) and (d) fly ash and (e) and (f) zirconia54
Figure 3.3 (a) SEM micrograph of as received zircon sand (b) particle size
distribution
Figure 3.4 Friction stir processing set-up
Figure 3.5 Schematic views of FSP process in steps: I Plate of known dimension
II Groove machining on the copper plate III compacting particulates in the grooves
IV Groove closure by passing pinless tool V Friction stir processing58
Figure 3.6 Schematic diagrams for sample extraction from the processed plates 59
Figure 3.7 Schematic views of the tensile specimen
Figure 3.8 Schematic diagrams for the pin on disc wear set-up63

Figure 4.1 Surface appearance of FSPed Cu/ZrSiO4 surface composite70
Figure 4.2 Cross-sectional macrostructure of FSPed Cu/ZrSiO4 surface composite
71
Figure 4.3 Optical micrograph at various locations within SZ of the composite (a)
towards advancing side at the top (b) towards retreating side on the top (a) at the
center towards advancing side (d) at the center towards retreating side (e) towards
advancing side at the bottom (f) towards retreating side on the bottom73
Figure 4.4 SEM micrograph of SZ of the composite at different magnifications 75
Figure 4.5 Optical micrograph at various locations within SZ of the composite (a)
towards advancing side at the top (b) towards retreating side on the top (a) at the
center towards advancing side (d) at the center towards retreating side (e) towards
advancing side at the bottom (f) towards retreating side on the bottom77
Figure 4.6 SEM micrograph of SZ of the composite at different magnifications 78
Figure 4.7 EBSD image (IPF + grain boundary) and corresponding grain size
distribution of (a) and (b) base copper, (c) and (d) processed copper without
reinforcement and (e) and (f) FSPed Cu/ZrSiO4 composite
Figure 4.8 SEM micrograph of fabricated composite Cu/ZrSiO ₄ and its binarized
image (b). The dark spots are Zircon particles and white spots are matrix81
Figure 4.9 Homogeneity curve for zircon particles
Figure 4.10 XRD pattern of fabricated Cu/ZrSiO4 surface composite83
Figure 4.11 Microhardness profile of FSPed copper with and without
reinforcement
Figure 4.12 Stress-strain curves of base copper, FSPed copper and FSPed
composite

Figure 4.13 Tensile fractographs of (a) base copper (b) FSPed copper (c) FSPed
composite
Figure 4.14 Wear loss v/s distance profile of base copper and FSPed copper with
and without reinforcement
Figure 4.15 Friction coefficient variation with time
Figure 4.16 SEM micrograph of worn surface (a) Pure Copper (b) Fabricated
Composites92
Figure 5.1 The surface appearance of FSPed Cu/FA surface composite101
Figure 5.2 The cross-sectional macrostructure of FSPed Cu/FA surface composite
Figure 5.3 SEM micrograph of SZ of the composite at different magnifications
104
Figure 5.4 Optical micrograph at various locations within SZ of the composite (a)
towards advancing side at the top (b) towards retreating side on the top (a) at the
centre towards advancing side (d) at the centre towards retreating side (e) towards
advancing side at the bottom (f) Interface
Figure 5.5 (a) EBSD image (IPF + grain boundary) and corresponding grain size
distribution of particles (b)
Figure 5.6 SEM micrograph of fabricated composite Cu/FA and its binarized
image (b). The dark spots are FA particles and white spots are a matrix110
Figure 5.7 Homogeneity curve for FA particles
Figure 5.8 XRD pattern of fabricated Cu/FA surface composite
Figure 5.9 Microhardness profile of FSPed Cu/FA surface composite113
Figure 5.10 Stress-strain curve of base copper FSPed Cu/FA surface composite
114

Figure 5.11 Tensile fractograph of FSPed Cu/FA surface composite
Figure 5.12 Wear loss v/s distance profile of base copper and FSPed Cu/FA
composite
Figure 5.13 Friction coefficient variation with time
Figure 5.14 SEM micrograph of the worn surface (a) Pure Copper (b) Fabricated
Composites
Figure 6.1 The surface appearance of FSPed Cu/ZrO ₂ surface composite127
Figure 6.2 The cross-sectional macrostructure of FSPed Cu/Zrconia surface
composite
Figure 6.3 Optical micrograph at various locations within SZ of the composite (a)
towards advancing side at the top (b) towards retreating side on the top (a) at the
centre towards advancing side (d) at the centre towards retreating side (e) towards
advancing side at the bottom (f) Interface
Figure 6.4 SEM micrograph of SZ of the composite at different magnifications
Figure 6.5 (a) EBSD image (IPF + grain boundary) and corresponding grain size
distribution of particles (b)
Figure 6.6 XRD pattern of fabricated Cu/ ZrO2 surface composite
Figure 6.7 SEM micrograph of fabricated composite Cu/ ZrO2 and its binarized
image (b). The dark spots are FA particles and white spots are a matrix135
Figure 6.8 Homogeneity curve for FA particles
Figure 6.9 Microhardness profile of FSPed Cu/ZrO2 surface composite137
Figure 6.10 Stress-strain curve of base copper FSPed Cu/ ZrO2 surface composite
Figure 6.11 Tensile fractograph of FSPed Cu/ZrO2 surface composite140

Figure 6.12 Friction coefficient variation with time	141
Figure 6.13 Wear loss v/s distance profile of base copper and FS	Ped Cu/ZrO2
composite	142
Figure 6.14 SEM micrograph of the worn surface (a) Pure Copper (b) Fabricated
Composite	143