The Evolution of Microstructures and Properties due to Materials Tool Interaction during Friction Stir Welding of Similar and Dissimilar Al and Cu Alloys

by

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LIST OF ABBREVIATIONS

FSW	Friction Stir Welding
AS	Advancing Side
RS	Retreating Side
FSP	Friction Stir Processing
BM	Base Metal
SiC	Silicon Carbide
HAZ	Heat Affected Zone
Vol.	Volume
Mg_5Si_6	Magnesium silicide
TWI	The Welding Institute
SZ	Stir Zone
NZ	Nugget Zone
min	Minute
rpm	Revolution Per Minute
Al-Mg-Si	Aluminum-Magnesium-Silicon
TEM	Transmission Electron Microscopy
Al_4Cu_9	Intermetallic Compound
Al_2Cu	Intermetallic Compound
AlCu	Intermetallic Compound
TMAZ	Thermomechanically Affected Zone
Al_2O_3	Aluminum Oxide
SMAT	Surface Mechanical Attrition Treatment
SNC	Surface Nano Crystallization

ECAP	Equal Channel Angular Processing
ECAE	Equal Channel Angular Extrusion
nm	Nanometer
MIG	Metal Inert Gas
UTS	Ultimate Tensile Strength
YS	Yield Strength
BMs	Base Metals
FESEM	Field Emission Scanning Electron Microscopy
EDX	Energy-Dispersive X-ray Spectroscopy
HRC	Rockwell Hardness
OM	Optical Microscope
AFM	Atomic Force Microscopy
OES	Optical Emission Spectrometry
ASTM	American Standard Testing of Materials
NaOH	Sodium Hydroxide
XRD	X-Ray Diffraction
Wt%	Weight Percent
At%	Atomic Percent

LIST OF SYMBOLS

Al-Mg-Si	Aluminum-Magnesium-Silicon
°C	Celsius Temperature
R_a	Surface Roughness, (nm)
R_{max}	Maximum Surface Roughness, (nm)
H_v	Hardness Value
H_0 and K_H	The Proper Constants
d	Grain Size, (μm or nm)
ρ	Dislocation Density
Kr	Material Constant
μ	friction coefficient
M	Interfacial Torque
R	Shoulder Radius, (mm)
F(r)	Axial Force, (Newton)
q_o	Friction Heat Input, (watts)
ω	Angular Velocity,(rad/sec)
N	Rotational Speed, (rad/sec)
Mn	Manganese
Zn	Zinc
Cu	Copper
kN	Kilonewton
R_1	As-Received Surface Roughness
R_2	Surface Roughness of Specimen Number Two
R_3	Surface Roughness of Specimen Number Three

R_4	Surface Roughness of Specimen Number Four
s	Second
W	Watt
Hz	Hertz
ml	Milliliter
g	Gram
kV	Kilovolt
mA	Milliampere
K	Kelvin
α	linear thermal expansion coefficient, (K^{-1})
ΔL	Change in Length of the Test Piece,(mm)
L_o	Initial Length of the Test Piece, (mm)
T_1	Reference Temperature, (K)
T_2	Test Temperature, (K)
kg	Kilogram
P_T	Applied Load, (Newton)
d_t	Arithmetic Mean of two Diagonal Lengths, (mm)
D	Shoulder Diameter, (mm)
A_c	Contact Area, (mm^2)
Q	Heat Flux, ($Watt/mm^2$)
wt.	Weight
C	Carbon
O	Oxygen
T_1	Threaded Tapered Cylindrical
T_2	Triangular

T_3	Square
cm	centimeter
No.	Number
Nos.	Numbers