LIST OF FIGURES

Figure No.	Title	Page
Fig: 1.1	Pulsed current wave form	2
Fig: 2.1	Cu-Ni Binary Phase Diagram	6
Fig: 2.2	Schematic diagram of (a) CC GTAW (b) PCGTAW	10
Fig: 2.3	A flowchart of Taguchi method for optimization	15
Fig: 2.4	Ishikawa Cause and Effect Diagram for PC GTAW process	24
Fig: 3.1	Experimental flow chart	29
Fig: 4.1	Base Metals of size 1000 x 500 x 5 mm (a) 90/10 Cu-Ni alloy plate (b)70/30 Cu-Ni alloy plate	30
Fig: 4.2	Single V butt welds	32
Fig: 4.3	Gas tungsten arc welding machine with automatic welding speed equipment	32
Fig: 4.4	Welding torch arrangement with automatic welding speed & filler wire (manually feeding)	33
Fig: 4.5	A schematic diagram of the GTAW joint bead made perpendicular to the plate rolling direction & tensile test specimen cut from weld	33
Fig: 4.6	Laser welding machine	35
Fig: 4.7	Laser welding machine particulars	36
Fig: 4.8	Schematic layout of $C0_2$ LASER beam welding	36

Fig: 4.9	Experiment set up for Laser welding	37
Fig: 4.10	Square butt joint	37
Fig: 4.11	LECO's LV700 Vickers hardness testing machine	38
Fig: 4.12	Bend test specimen	39
Fig: 4.13	Bend test	39
Fig: 4.14	Tensile specimen used as per ASTM- E8	40
Fig: 4.15	Universal Testing Machine(UTM) for Tensile test	40
Fig: 4.16	Failure of the sample during tensile testing	41
Fig: 4.17	Optical Microscope (OM)	42
Fig: 4.18	JOEL JSM 6610 SEM	42
Fig: 4.19	Basic Electrochemical System for Dynamic polarization	43
Fig: 4.20	Dimensions of specimen for corrosion test	43
Fig: 5.1	Effect of CC GTAW on microhardness of 90/10 Cu-Ni alloy welds	45
Fig: 5.2	Bent test of CC GTAW joints	46
Fig: 5.3	Effect of CC GTAW on Tensile strength of 90/10 Cu-Ni alloy welds	46
Fig: 5.4	Microstructures of (a) BM of 90/10 Cu-Ni alloy, & CC GTAW of 90/10 Cu-Ni alloy welds at (b) FZ (c) Interface (d) HAZ	47
Fig: 5.5	Effect of CC GTAW on microhardness of 70/30 Cu-Ni alloy welds	49
Fig: 5.6	Effect of CC GTAW on Tensile strength of 70/30 Cu-Ni alloy welds	49
Fig:5.7	Microstructures of (a) BM of 70/30 Cu-Ni alloy , & CC GTAW of 70/30 Cu-Ni alloy welds at (b) FZ (c) Interface (d) HAZ	50

Fig: 5.8	Comparison of mean effect and S/N ratio of tensile strength of 90/10 Cu-Ni alloy welds	62
Fig: 5.9	Percentage of contribution of factors (Means) of PCGTAW of 90/10 Cu-Ni alloy welds	63
Fig: 5.10	Comparison of mean effect and S/N ratio of tensile strength of PC GTAW of 70/30 Cu-Ni alloy welds	67
Fig: 5.11	Percentage of contribution of factors (Means) of PC GTAW of 70/30 Cu-Ni alloy welds	68
Fig: 5.12	Effect of peak current on microhardness of PC GTAW of 90/10 Cu-Ni welds	73
Fig: 5.13	Effect of base current on microhardness of PC GTAW of 90/10 Cu-Ni welds	73
Fig: 5.14	Effect of pulse frequency on microhardness of PC GTAW of 90/10 Cu-Ni welds	74
Fig: 5.15	Effect of welding speed on microhardness of PC GTAW of 90/10 Cu-Ni welds	74
Fig: 5.16	Failure location of PC GTAW joint during tensile test: (a) top view and (b) cross sectional view	74
Fig: 5.17	Effect of peak current on tensile strength of PC GTAW of 90/10 Cu-Ni welds	75
Fig: 5.18	Effect of base current on tensile strength of PC GTAW of 90/10 Cu-Ni welds	75
Fig: 5.19	Effect of pulse frequency on tensile strength of PC GTAW of 90/10 Cu-Ni welds	76
Fig: 5.20	Effect of welding speed on tensile strength of PC-GTAW	

of 90/10 Cu-Ni welds 76

Fig: 5.21 Effect of peak current on joint efficiency (%) of PC GTAW of 90/10 Cu-Ni welds 77

Fig: 5.22 Effect of base current on joint efficiency (%) of PC GTAW of 90/10 Cu-Ni welds 77

Fig: 5.23 Effect of pulse frequency on joint efficiency (%) of PC GTAW of 90/10 Cu-Ni welds 78

Fig: 5.24 Effect of welding speed on joint efficiency (%) of PC GTAW of 90/10 Cu-Ni welds 78

Fig: 5.25 Characteristics of PC GTAW of 90/10 Cu-Ni alloy welds (a) PCGTAW- FZ (OM), (b) PCGTAW- FZ (SEM), and (c) EDS result 79

Fig: 5.26 Effect of peak current on fusion zone microstructure (50µm): (a) 200 A (b) 210A (c) 220 A, and (d) 230 A 81

Fig: 5.27 Effect of base current on fusion zone microstructure (50µm): (a) 95 A (b) 105 A (c) 115 A, and (d) 125 A 82

Fig: 5.28 Effect of pulse frequency on fusion zone microstructure (50µm): (a) 0.5Hz (b) 1Hz (c) 3Hz, and (d) 5Hz 84

Fig: 5.29 Effect of pulse frequency on fusion zone microstructure (50µm): (a) 140 mm/min (b) 150 mm/min (c)160 mm/min, and (d)170 mm/min 85

Fig: 5.30 Effect of peak current on microhardness of PC GTAW of 70/30 Cu-Ni welds 87

Fig: 5.31 Effect of base current on microhardness of PC GTAW of

	70/30 Cu-Ni welds	88
Fig: 5.32	Effect of pulse frequency on microhardness of PC GTAW of 70/30 Cu-Ni welds	88
Fig: 5.33	Effect of welding speed on microhardness of PC GTAW of 70/30 Cu-Ni welds	88
Fig: 5.34	Bend test for PC GTAW joints	89
Fig: 5.35	Effect of peak current on tensile strength of PC GTAW of 70/30 Cu-Ni welds	90
Fig: 5.36	Effect of base current on tensile strength of PC GTAW of 70/30 Cu-Ni welds	90
Fig: 5.37	Effect of pulse frequency on tensile strength of PC-GTAW of 70/30 Cu-Ni welds	90
Fig: 5.38	Effect of welding speed on tensile strength of PC GTAW of 70/30 Cu-Ni welds	91
Fig: 5.39	Effect of peak current on joint efficiency (%) of PC GTAW of 70/30 Cu-Ni welds	91
Fig: 5.40	Effect of base current on joint efficiency (%) of PC GTAW of 70/30 Cu-Ni welds	92
Fig: 5.41	Effect of pulse frequency on joint efficiency (%) of PC GTAW of 70/30 Cu-Ni welds	92

Fig: 5.42 Effect of welding speed on joint efficiency (%) of PC-GTAW of 70/30 Cu-Ni Welds 92

Fig: 5.43 Characteristics of PC GTAW of 70/30 Cu-Ni alloy welds (a) PC GTAW- FZ (OM), (b) PC GTAW- FZ (SEM), and (c) EDS result 93

Fig: 5.44 Effect of peak current on fusion zone microstructure (50µm): (a) 200 A (b) 210A (c) 220 A, and (d) 230 A 95

Fig: 5.45 Effect of base current on fusion zone microstructure (50µm): (a) 95 A (b) 105 A (c) 115 A, and (d) 125 A 96

Fig: 5.46 Effect of pulse frequency on fusion zone microstructure (50µm): (a) 0.5Hz (b) 1Hz (c) 3Hz, and (d) 5Hz 98

Fig: 5.47 Effect of welding speed on fusion zone microstructure (50µm): (a) 140 mm/min (b) 150 mm/min (c) 160 mm/min, and (d) 170 mm/min 99

Fig: 5.48 LBW of 90/10 Cu-Ni alloy welds of (a) Welding face side and (b) Root side 100

Fig: 5.49 Effect of Laser Beam welding (LBW) on Microhardness of 90/10 Cu-Ni alloy welds 101

Fig: 5.50 Effect of Laser Beam welding (LBW) on Tensile strength of 90/10 Cu-Ni alloy welds 102

Fig: 5.51 Effect of Laser Beam welding (LBW) on Joint efficiency (%) of 90/10 Cu-Ni alloy welds 103

Fig: 5.52 Optical micrographs, 200X (50µm), showing effect of Laser Beam Welding (LBW) speeds on Microstructures (FZ) of 90/10 Cu-Ni alloy welds 104

Fig: 5.53 Optical micrographs, 200X (50µm), showing effect of Laser Beam Welding (LBW) speeds on Microstructures (HAZ) of 90/10 Cu-Ni alloy welds 105

Fig: 5.54 SEM, 1000 X (10µm), showing effect of Laser Beam Welding (LBW) speeds on Microstructures (FZ) of 90/10 Cu-Ni alloy welds 105

Fig: 5.55 Tensile fractures of LBW of 90/10 Cu-Ni alloy welds 105

Fig: 5.56 SEM, 1000 X (10µm), showing tensile fractured surface of 90/10 Cu-Ni alloy (a) BM (b) welding speed 2.0 m/min 106

Fig: 5.57 LBW of 70/30 Cu-Ni alloy welds of (a) Welding face side and (b) Root side 107

Fig: 5.58 Effect of Laser Beam welding (LBW) on Microhardness of 70/30 Cu-Ni alloy welds 108

Fig: 5.59 Effect of Laser Beam welding (LBW) on Tensile strength of 70/30 Cu-Ni alloy welds 109

Fig: 5.60 Effect of Laser Beam welding (LBW) on Joint efficiency (%)

of 70/30 Cu-Ni alloy welds 109

Fig: 5.61 Optical micrographs, 200X (50µm), showing effect of Laser Beam Welding (LBW) speeds on Microstructures (FZ) of 70/30 Cu-Ni alloy welds 110

Fig: 5.62 Optical micrographs, 200X (50µm), showing effect of Laser Beam Welding (LBW) speeds on Microstructures (HAZ) of 70/30 Cu-Ni alloy welds 111

Fig: 5.63 SEM, 1000 X (10µm), showing effect of Laser Beam Welding (LBW) speeds on Microstructures (FZ) of 70/30 Cu-Ni alloy welds 111

Fig: 5.64 Tensile test fractured specimens of LBW of 70/30 Cu-Ni alloy welds 112

Fig: 5.65 SEM, 1000 X (10µm), showing tensile fractured surface of 70/30 Cu-Ni alloy (a) BM (b) welding speed 1.5 m/min 112

Fig: 5.66 Bend test for LBW joints 113

Fig: 5.67 Potentiodynamic polarisation curves of 90/10 Cu-Ni alloy welds and aged samples in aerated 3.5%NaCl solution 115

Fig: 5.68 EDS results of BM of 90/10 Cu-Ni alloy 116

Fig: 5.69 EDS results of particle at weld centre of PCGTAW of 90/10 Cu-Ni alloy welds 116

Fig: 5.70 EDS results of particle at weld centre of LBW of 90/10 Cu-Ni

	alloy welds	116
Fig: 5.71	EDS results of particle at weld centre of CCGTAW of 90/10 Cu-Ni alloy welds	116
Fig: 5.72	Microstructures (FZ, 200X) of pitting corrosion of 90/10 Cu-Ni alloy welds (aerated 3.5%NaCl solution)	117
Fig: 5.73	Potentiodynamic polarisation curves of 70/30 Cu-Ni alloy welds and aged samples in aerated 3.5%NaCl solution	118
Fig: 5.74	EDS results of BM of 70/30 Cu-Ni alloy welds	119
Fig: 5.75	EDS results of particle at weld centre of LBW of 70/30 Cu-Ni alloy weld	119
Fig: 5.76	EDS results of particle at weld centre of PCGTAW of 70/30 Cu-Ni alloy welds	120
Fig: 5.77	EDS results of particle at weld centre of CCGTAW of 70/30 Cu-Ni alloy welds	120
Fig: 5.78	Microstructures (FZ, 200X) of pitting corrosion of 70/30 Cu-Ni alloy welds (aerated 3.5%NaCl solution)	121
Fig: 5.79	Micro hardness results –CC GTAW, PC GTAW & LBW of 90/10 Cu-Ni alloy welds	122
Fig: 5.80	Tensile strength results –CC GTAW, PC GTAW & LBW of 90/10 Cu-Ni alloy welds	122

Fig: 5.81	Joint efficiency results –CC GTAW, PC GTAW & LBW of 90/10 Cu-Ni alloy welds	123
Fig: 5.82	Microstructures (FZ) results–90/10 Cu-Ni alloy of (a) CC GTAW (b) PC GTAW, & (c) LBW	123
Fig: 5.83	Microstructures (HAZ) results–90/10 Cu-Ni alloy of (a) CC GTAW (b) PC GTAW, & (c) LBW	124
Fig:5.84	Microstructures (Tensile fracture) results–90/10 Cu-Ni alloy of (a) BM (b) CC GTAW, (c) PC GTAW & (d) LBW, SEM, 1000X (10μm)	124
Fig: 5.85	Micro hardness results –CC GTAW, PC GTAW & LBW of 70/30 Cu-Ni alloy welds	125
Fig: 5.86	Tensile strength results –CC GTAW, PC GTAW & LBW of 70/30 Cu-Ni alloy welds	126
Fig: 5.87	Joint efficiency results – CC GTAW, PC GTAW & LBW of 70/30 Cu-Ni alloy welds	126
Fig: 5.88	Microstructures (FZ) results–70/30 Cu-Ni alloy of (a) CC GTAW (b) PC GTAW,(c) LBW	127
Fig: 5.89	Microstructures (HAZ) results–70/30 Cu-Ni alloy of (a) CC GTAW (b) PC GTAW, (c) LBW	127
Fig: 5.90	Microstructures (Tensile fracture) results–70/30 Cu-Ni alloy of(a) BM	

(b) CC GTAW (c) PC GTAW, (d) LBW, SEM, 1000X (10µm) 128

Fig: 5.91 Bent specimens of (a) LBW joints (b) PC GTAW joints

(c) CC GTAW joints 128

Fig: 5.92 Weld bead width of CC GTAW ,PC GATW & LBW 129