6.1 MECHANICAL PROPERTIES & MICROSTRUCTURES OF 90/10 & 70/30 Cu-Ni ALLOY WELDS

1. CC GTAW of 90/10 & 70/30 Cu-Ni alloy welds exhibited coarse grain sizes in FZ & HAZ and resulted in inferior weld mechanical properties than PC GTAW.

2. By Taguchi method the optimisation of PC GTAW process parameters and predicted optimum ultimate tensile strength values of 90/10 & 70/30 Cu-Ni alloys welds were obtained as follows:
   a) PC (210 A), BC (105A), PF (1 Hz) & WS (150 mm/min) for 90/10 Cu-Ni alloy welds.
   b) PC (210 A), BC (105A), PF (3 Hz) & WS (150 mm/min) for 70/30 Cu-Ni alloy welds.

3. The influences of optimum pulsed current parameters on the mechanical and metallurgical properties of gas tungsten arc welded 90/10 & 70/30 Cu-Ni alloys. From this investigation, the following important conclusions are derived:
   a) 90/10 & 70/30 Cu-Ni alloys were successfully joined without any macro level defects by a pulsed current gas tungsten arc welding process under the following range of process parameters: peak current of 200 A to 230 A; base current of 95 A to 125 A; pulse frequency of 0.5 Hz to 5 Hz and welding speed time of 140 mm/min to 170 mm/min.
   b) 90/10 Cu-Ni alloy joints fabricated with a peak current of 210 A, base current of 105 A, pulse frequency of 1 Hz and welding speed of 150 mm/min showed higher tensile properties than their counterparts. These pulsed current parameters yielded an optimum heat input of 0.68 kJ/mm.
c) 70/30 Cu-Ni alloy joints fabricated with a peak current of 210 A, base current of 105 A, pulse frequency of 3 Hz and welding speed of 150 mm/min showed higher tensile properties than their counterparts. These pulsed current parameters yielded an optimum heat input of 0.68 kJ/mm.

d) The formation of fine grains in the weld region, higher fusion zone hardness and uniformly distributed precipitates are the main reasons for the superior tensile properties of the above joints.

4. LBW experiments on 90/10 & 70/30 Cu-Ni alloy welds were conducted with various welding speeds (i.e 1.0 m/min, 1.5m/min, 2.0m/min & 2.5 m/min). The welding speeds 2.0 m/min (90/10 Cu-Ni) & 1.5 m/min (70/30 Cu-Ni) exhibited fine grains at FZ and resulted in superior mechanical properties compared to other welding speeds.

5. Of all the three welding techniques, PC GTAW of 90/10 Cu-Ni alloys exhibited superior mechanical properties compared LBW & CC GTAW.

6. The tensile strength values of LBW joints were less than the PC GTAW joints but the difference in values were minute because copper cannot be melted easily by LBW because of its high reflectivity & high thermal conductivity and % of copper is 20% more when compared to that of 70/30 Cu-Ni alloy.

7. PC GTAW & LBW of 90/10 Cu-Ni welds exhibited fine, equiaxed & uniformly distributed grains at FZ and resulted in superior mechanical properties. It was also observed that, there was an improvement of 9-10 % & 8-9% respectively in mechanical properties than CC GTAW.

8. PC GTAW & LBW of 70/30 Cu-Ni welds exhibited fine, equiaxed & uniformly distributed grains at FZ and resulted in superior mechanical properties. It was also observed that, there was an improvement of 13-14 % & 15-17% respectively in mechanical properties than CC GTAW.
9. CC GTAW of 90/10 & 70/30 Cu-Ni alloy welds exhibited coarse grains, more distortion, uncontrolled segregation and epitaxial grains in the FZ, & HAZ and resulted in inferior mechanical properties.

10. PC GTAW exhibited better mechanical properties than LBW of 90/10 Cu-Ni alloy welds. LBW exhibited better mechanical properties than PC GTAW of 70/30 Cu-Ni alloy welds.

11. Economically, the cost of LBW is more than PC GTAW. So, PC GTAW is mostly preferred for both the 90/10 and 70/30 Cu-Ni alloy welds. If 70/30 Cu-Ni alloy welds are particular about the tensile strength, in such case LBW is preferred.

12. Of all the three welding techniques, corrosion potential Ecorr and Epit values of LBW of 90/10 & 70/30 Cu-Ni alloy welds exhibited more positive values (less negative values) than PC GTAW & CC GTAW. It resulted in high pitting corrosion resistance.

13. Of all the three welding techniques, corrosion potential Ecorr and Epit values of CC GTAW of 90/10 & 70/30 Cu-Ni alloy welds exhibited less positive values (more negative values) than PC GTAW & LBW. It resulted in low pitting corrosion resistance.

14. The three welding techniques of 70/30 Cu-Ni alloy welds showed better pitting corrosion resistance than 90/10 Cu-Ni alloy welds because 70/30 Cu-Ni alloys have higher % of Ni.

15. CC GTAW, PC GTAW & LBW joints of dimensions (100 mm length x 30mm width x 5 mm thk.) were bent at angle of 180° through bend test namely root bend and face bend. There was no cracking observed, irrespective of whether the weld face was on the compression side or on the tension side.
16. Of all the three welding techniques, tensile fracture of PC GTAW joints through SEM fractography revealed voids in wide range of sizes, shallow dimples when compared to CC TAW & LBW joints. PC GTAW joints exhibited less ductile nature of fracture thus resulted in superior mechanical properties compared to CC GTAW & LBW joints.

17. On comparing CC GTAW & LBW, CC GTAW joints exhibited voids with various sizes & deep dimples and its fracture is more ductile in nature whereas LBW joints exhibited voids with various sizes & shallow dimples and its fracture is less ductile in nature and thus LBW joints exhibited superior mechanical properties.

18. SEM fractography of CC GTAW of tensile fracture joints exhibited voids and isolated pockets of deep shallow dimples leads to increase in ductile nature of failure welds than PC GTAW and LBW joints.

19. From the SEM-EDS values, LBW & PC GTAW joints exhibited high % of Cu, & Ni, less % of Zn and fine grains in FZ, this resulted in high pitting corrosion resistance and superior mechanical properties than CC GTAW.

20. From the SEM-EDS values, CC GTAW joints exhibited less % of Cu, & Ni, more % of Zn and coarse grains in FZ, this resulted in low pitting corrosion resistance and inferior mechanical properties than PC GTAW & LBW.

6.2 SCOPE FOR FUTURE WORK

a) Solid state welding processes like FW and Friction stir welding can be applied for the improvement of mechanical properties of 90/10 & 70/30 Cu-Ni alloys.
b) Pulse Laser welding can be applied for improvement of mechanical properties of 90/10 & 70/30 Cu-Ni alloys.