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Title:- Some studies on submerged arc welding of steel

ABSTRACT

This study was conducted to evaluate the performance of the fluxes by using scientific methodology, so that optimum flux compositions to give specific mechanical performance characteristics can be made. The response surface methodology has been used for design of fluxes and the fluxes were made by using agglomeration technique. As the performance of weld metal (WM) is characterized by impact strength, ultimate tensile strength, percentage elongation and hardness consequently, multi objective optimization was obtained by using Grey Relational Analysis. Moreover, principal component analysis was used to evaluate the relative weighting values for the various mechanical properties of the weldments.

The effects of variations in flux compositions on the bead geometry, width of heat affected zone (HAZ), area of penetration, heat affected area, dilution, mechanical properties of mild steel, element transfer and microstructure weld have been studied. Base fluxes comprising of $CaO–SiO_2–Al_2O_3$ were designed by using central composite design. CaF_2, FeMn and NiO were added as alloying elements in the range of (2–8) % to the base fluxes and C, Si, Mn, S, P and Ni content transfers were studied.

The individual alloying additives in the flux did not show a definite effect on bead geometry parameter but the experiments confirmed that acidity ratio has a definite effect on the bead geometry parameters. The elements transfers to the welds also were correlated with the bead geometry parameters. The bead width has an increasing trend with Ni proportion transfer to the weld and it also increases with (BI) of the flux. The penetration is seen to be increased with NiO additive, while it is reduced with increase of CaF_2 content in the flux. The Ni and Mn contents have been correlated with the $\frac{W}{A}$ ratio, bead width to cross sectional area of the weld. The $\frac{W}{P}$, after an initial decrease, it increases with increase in oxygen content of the weld. In this study as the ratio of the base constituents was constant, so, the effect of flux additives is seen on bead geometry and shape relationship.

The effect of flux composition on width of the HAZ and dilution showed that the width of HAZ is reduced with increase of NiO content in the flux and also with increasing Ni content in the welds. However, the width of HAZ is increased with increasing dilution of the welds but it decreased with increase in basicity index (BI) of the flux. The HAZ width is low in both the cases when the oxygen content is either very low or very high.

Mechanical testing and elements transfer studies on bead on plate welds established, that high impact energy could be achieved at low Mn, C and Ni contents in the weld. Carbon additions were found to increase the ultimate tensile strength but the impact energy was reduced. However, on lowering carbon content by varying flux composition high impact strength was obtained without compromising the ultimate strength and elongation of the weld. The microstructure, mechanical properties and HAZ dimensions also have been correlated with the basicity index (BI) of the flux, carbon equivalent and weld oxygen content.

The inclusion types and microstructures of the weld metals were characterized using optical microscopy. The microstructure was observed to comprise a mixture of pearlite and ferrite. The pearlite content was increased with increase of BI of the flux. The microstructure was also correlated with the elements transferred to the welds. More pearlite content was observed in those welds which were having low C, Mn and Ni contents and these welds were having high toughness and good tensile strength. Various elements transferred to the welds, were measured using wet chemical analysis. The elements transfer study revealed that very low silicon content was transferred to the weld metal at a particular composition of the flux. However, high carbon content was observed in these welds and which were also associated with poor impact strength. From the elements transfer study it was also established that high Ni and high Mn transfer to the welds were detrimental to mechanical properties. Weld dilution also has been correlated with the grain size and the pearlite contents in the weldment. From this, it has been concluded that the grain size is reduced with increase in dilution while, pearlite content and ultimate tensile strength (UTS) increases with increasing dilution.

From the correlation of impact energy and inclusion types, it has been established that silicate type inclusions were associated with high toughness but alumina type inclusions reduced the toughness drastically. The sulphide type inclusions were generally not found detrimental to toughness and these welds were also found to have good UTS. However, welds having high Ni contents with sulphide inclusions were found to have low impact energy. Globular oxide inclusions were also correlated with good impact strength and UTS.

Various studies of this research corroborate the following outcomes.

1. A scientific methodology may be developed for flux formulations rather than the prevalent method of hit and trial.
2. Selection of flux constituents can be done successfully based on chemical kinetics as derived from steel making so that homogeneous composition of base metal and weld metal can be attempted.
3. Proper characterization of fluxes for their welding behaviour can be done so that the requirement of mechanical properties for specific application can be fulfilled.
4. Subsequently effects of individual element in the flux on the properties of weld metal can be correlated.
5. The alloying elements can be categorized with special regard to their impact on welding behaviour and thus the cheaper fluxes can be made in future. For ascertaining it, design of experiment has been employed in this present study.