ABSTRACT

This study aims at improving the weldability and strength of similar and dissimilar joints of steel and aluminium in resistance spot welding (RSW) by incorporating an interlayer of carbonaceous nanomaterial. At the outset, comparative investigations were done on the effect of the incorporation of graphene nanoplatelets (GNPs) and multi-walled carbon nanotubes (MWCNTs) as interlayers in the RSW of similar AISI-1008 steel sheets. Lap shear tests were performed to select the interlayer that provided the better weld strength of the joints. The incorporation of GNPs as interlayer reported a higher weld strength enhancement of ~64% at a similar weld parameter as compared to the MWCNTs interlayer. Hence, the feasibility of the GNPs as an interlayer was tested in the RSW of AISI-1008 steel and Al-1100 alloy and a significant enhancement of ~124% in the lap shear strength was reported at an optimised welding parameter. An in-depth study on the presence and morphologies of the intermetallic compounds (IMCs) developed at the Al-steel interface viz. $FeAl_3$, Fe_2Al_5, and Fe_4Al_{13} were carried out. The study is further extended from the application viewpoint to automotive-grade steels like CR-210 steel and DP-780 steel. At first, RSW of CR-210 steel sheets was carried out employing GNPs as an interlayer. A fixture of the cross-tensile test was developed, and mechanical tests such as lap shear tests and cross-tensile tests were performed for the weldments. An enhancement of ~124% in the lap shear strength at the best welding parameter with the incorporation of GNPs as an interlayer was reported. This enhancement in the weld strength was validated with an in-depth investigation of the microstructural variations using several microscopy techniques. Similarly, the RSW of CR-210 steel and DP-780 steel was performed using GNPs as an interlayer for automotive applications. An improvement of ~36% was reported in the lap shear strength with the incorporation of the GNPs interlayer. Also, the favourable pull-out failure mode originating from the weaker CR-210 steel side was obtained. Microhardness and grain size variation at different zones was studied and an in-depth investigation of the interfacial bonding mechanisms and strengthening mechanisms was carried out. Finally, RSW was employed for the fabrication of patch blanks with GNPs as an interlayer at the best welding parameter obtained from the lap shear and cross-tension tests of CR-210 and DP-780 steel joints. Stretch forming was done for the fabricated patch blanks and the formability characterisation of the stretch-formed domes was performed by strain distribution analysis and limiting dome height tests. It was observed from the strain distribution analysis that strain localisation occurred at the CR-210 steel blank away from the spot welds owing to excessive thinning, which ultimately led to the failure of the patch blanks. Hence, the optimised process parameter combination obtained in this study can be recommended for the resistance spot welding of various similar and dissimilar materials with the incorporation of carbonaceous interlayers for tailored applications such as in automotive industries.

***Keywords**:* Graphene nanoplatelets; Interlayers; Multi-walled carbon nanotubes; Patch blank; Resistance spot welding; Stretch forming