Chapter 5: Conclusions

This experimental work led did to some important finding, and the same have been summarized below as conclusions:-

1. The GMAW of ferritic stainless steel SS409L can be successfully carried out with ER304L electrode, and defect free welds could be obtained on 3 mm thick plates while performing square butt welding.

2. The grain size in the weld metal increases with the heat input upto a certain value (whenin the grain coarsening effect due to heat input is dominant), but after that on increasing the heat input, the grain size was found to decrease (when the formation of other phase is dominant due to higher value of Cr/Ni equivalent ratio). The mechanical properties follow the trends seen in grain size and properties were observed to improve and deteriorate with the corresponding the decrease and increase in the grain size.

3. The grains obtained in the weld metal were found to be fine because of the use of austenitic grades filler wire. The austenite phase formed after solidification restricted the grain growth of the ferrite grains formed after the solidification of the weld. The average grain size obtained in the weld metal were smaller than those present in the unaffected base material.

4. Coarse grains were obtained in the heat affected zone. The base material was fully ferritic and unrestricted grain growth occurred in the heat affected zone during the heating and cooling cycle. The grains observed in the heat affected zone were considerably larger than those found in the weld metal or the unaffected base material.

5. Because of the coarse grain size, all GMAW welded samples had the least strength in the HAZ. Therefore, all the transverse tensile test specimens fractured in the HAZ during tensile testing irrespective of the process parameters used during welding.

6. The Charpy impact toughness and the hardness values obtained in the weld metal were higher than those obtained in the base material and the HAZ. The higher values of impact toughness and hardness were due to the smaller grain size of the weld metal.

7. The welds produced at different heat input caused considerable changes in strength, hardness, and Charpy impact toughness in both the weld metal and the HAZ. The Charpy impact toughness and hardness were found to have increased with the increase in heat input. However, on further increasing the heat input beyond 374 J/mm, the hardness and impact toughness decreased. The corresponding values of grain size obtained also followed the similar trend.

8. Although, the weld mechanical properties could be improved to some extent, the mechanical properties in the HAZ continued to be much inferior than those of the base material and the weld metal. GMAW also resulted in the production of tensile residual stresses in some portion (WMZ and the BMZ) of the weldment.

9. FSP can be used as a technique to refining the grains of the HAZ of gas metal arc welded ferritic stainless steel plate. Although, through welding of thick plates of ferritic stainless steel using FSW is difficult, FSP can be successfully carried out up to 1.5 mm from the surface.

10. Thermally associated stirring of material due to movement of the pin of the FSP tool causes grain refinement in the friction stir processed sample. Grain refinement produced depends upon the strain rate and the temperature generated due to FSP.

11. The mechanical properties like hardness, tensile strength and Charpy impact toughness in the weldment improved after performing FSP. The entire region of the weldment after FSP was found to possess only compressive residual stresses, and tensile residual stresses were not observed in any sample after FSP. This was in contrast to what was observed after GMAW.

12. The friction stir processing parameters affected the mechanical properties obtained in the processed region. On increasing rotational speed to processing speed ratio, grain size was found to have decreased, leading to improved mechanical properties. Whereas, on increasing shoulder diameter, the grain size increased, causing a decrease in hardness.

13. The weld metal and the base material possesses tensile longitudinal residual stress, whereas HAZ possesses compressive longitudinal residual stress after GMAW. But, after carrying out the FSP operation, the tensile longitudinal residual stress of the weld metal get converted into the compressive residual stress. The magnitude of the compressive residual stress was also much higher than what was observed in the HAZ after GMAW. Thus, the tensile residual stress of the GMAWed plates was completely removed upon carrying out FSP and converted into the compressive residual stress.

14. The response to the MBN signal is varied in the BMZ, HAZ and WMZ due to variation in grain size of different zones. Change in material properties upon friction stir processed plates used in this study caused variation in micromagnetic response of the material.

15. MBN technique can be successfully used for characterisation of the welded plate as well as the processed plate.

16. An increase in micro-hardness along with associated grain refinement caused a reduction in the RMS value of the MBN signal. The variation in the different response parameters of the MHL depends upon several factors such as grain size, process parameters (MFI and magnetising frequency).