CHAPTER 5

CONCLUSIONS AND SCOPE FOR FUTURE WORK

5.1 CONCLUSIONS

Based on the experiments and test results of the work, it is concluded that:

- The Ti-6Al-4V - Inconel 718 joint dissimilar materials are weldable using diffusion bonding process. A maximum joint efficiency of 45.9% is achieved corresponding to the process parameters temperature 850°C, stress 20 MPa and time 2 hours. The transverse hardness survey carried out at their joint interface revealed that increase in hardness at the interface is higher in the samples diffusion bonded at 900°C than at 850°C. This is in good correlation with the EDS analysis using which it is postulated that the intermetallics formed at the interface in the samples were different for different temperatures. Ti$_2$Ni occurs at 900°C whereas TiNi$_3$ and TiNi occur at 850°C.

- The Ti-6Al-4V - SS 304L joint dissimilar materials are weldable using diffusion bonding process. A maximum joint efficiency of 64.4% is achieved corresponding to the process parameters temperature 800°C, stress 20 MPa and time 3 hours. The transverse hardness survey carried out at their joint interface revealed that increase in hardness at the interface is
higher in the samples diffusion bonded at 850°C than at 800°C. This is in good correlation with the EDS analysis using which it is postulated that the intermetallics formed at the interface in the samples were different, namely TiFe at 850°C and TiFe$_2$ at 800°C.

- The Ti-6Al-4V - Inconel 718 joint dissimilar materials are weldable using friction welding process. A maximum joint efficiency of 28% is achieved corresponding to the process parameters rotational speed of 1000 rpm, upset load of 6 ton and friction load of 2 ton. This is in good correlation with the EDS analysis using which it is postulated that uniformly distributed Ti$_2$Ni and $\beta$-Ti at the interface are present.

- The Ti-6Al-4V - SS 304L dissimilar materials are weldable using friction welding process. A maximum joint efficiency of 70% is achieved corresponding to the process parameters rotational speed of 1500 rpm, upset load of 6 ton and friction load of 4 ton.

- In both the dissimilar material combinations in each of the solid state joining process, there are certain parameters range beyond which hard zones form at the interface due to formation of intermetallics, leading to reduction in joint efficiency.

- The results of ultrasonic C-scan analyses on diffusion bonded joints of the two material combinations are in good correlation with their joint efficiency. However, no useful information is obtained from the results of ultrasonic C-scan analyses on friction welded joints as the interface region in friction welded joints is not flat and parallel to the top surface.
The results of SEM-EDS analyses on diffusion bonded joints and friction welded joints of the two material combinations are in good correlation with the transverse hardness survey carried out at their joint interface.

5.2 SCOPE FOR FUTURE WORK

The work can be further extended as below:

- Analysis on “Design of Experiments (DOE)” can be attempted to decide the number of experiments and the process parameters.
- The effect of post weld heat treatment on joint characteristics can be for each of the two solid state welding processes.
- The effect of surface roughness of the materials on joint characteristics can be analysed in both diffusion bonding and friction welding processes.
- The SEM-EDS results can further be analysed to find out the intermetallic compounds and other undesirable phases formed at the interface of the joints.
- Studies on diffusion co-efficients for inter-diffusion of elements based on SEM-EDS results can be carried out.
- The results of various experiments carried out can be combined with the detailed EDS analysis to model the diffusion and can be used to deduce diffusion time constants.
- The suitability of ultrasonic C-scan system for NDE of joints made by other welding processes can be investigated.