# Chapter 7 Conclusions and Scope for Future Work

## 7.1 Conclusions

Nowadays the efforts have been made by various investigators to enhance the engineering properties of the Al-Si alloys and develop the defect free products at minimum cost. The properties such as hardness, wear resistance etc of the Al-Si alloys increased with increase in the Si wt.%. Different bulk processing techniques have been used to produce such Al-Si alloy products, but it was very difficult and challenging due to the presence of coarse Si particles in the matrix. The coarse microstructure in the matrix increases when increasing the Si wt.% in the alloy. Therefore, in the present research work, the deformation behavior of the complex Al-Si alloys have been investigated through bulk processing techniques by varying the Si wt.%. Due to this, the three different compositions of Al-Si alloy such as Al-18Si-2.5Cu-0.6Fe, Al-11Si-2.5Cu-0.6Fe, and Al-7.4Si-2.5Cu-0.6Fe were cast and forged through the open die, impression die and converging dies under different processing conditions. During the process, the effect of various bulk processing parameters such as working temperatures, aspect or reduction ratios, forming speed and interfacial friction conditions on microstructural features and tribo-mechanical characteristics of the alloy have been analyzed during forging. The important findings are summarized below:

1. The as-cast microstructure of the Alloys A and B comprise of coarse primary and needle-shaped eutectic Si particles along with complex intermetallic compounds randomly disperse in the Al matrix. However, the Alloy C contains coarse needle and plate-shaped eutectic Si particles and such intermetallic compounds. Such coarse microstructures were formed due to non-uniform cooling rate during solidification.

2. The bulk processing of the Alloys A and B though open die forging at room temperature and 300°C, and also impression die forging at room temperature was not feasible and generates severe surface cracks in the outer periphery of the preform. It may be due to the presence of the coarse primary Si and intermetallic compounds which imitates stress concentration in the Al matrix and in turn severe surface cracks.
3. The open die forging of the Alloy C at room temperature and 300°C produces few minute micro-cracks in the outer surface of the preform. While in the impression die forging crack-free product was obtained at room temperature. The micro-cracks were formed due to the presence of the needle-shaped eutectic Si and intermetallic particles.
4. The impression and converging die forging of the Alloys A, B, and C at elevated temperatures of 300, 400 and 500°C produces defect-free forged products under both the lubricating and unlubricating conditions. It may be attributed to the softening of the alloys at the elevated working temperature which induced ductility during processing.
5. The forging load was maximum for test samples having a higher aspect ratio (h/d=1.20) in impression die and reduction ratio (R=2.0) in converging die during bulk processing. It may be due percentage deformation of the alloy was higher at h/d=1.20 (35%) and R=2.0 (51%) which needs higher forging load.
6. The microstructural refinement occurred during forging at elevated temperatures of 300, 400 and 500°C. It may be attributed to the precipitation of elemental silicon and intermetallic compounds containing Cu, and Fe giving rise to finer precipitates during homogenization. Along with this, fracture and fragmentation and uniformly dispersion of the brittles Si particles in the matrix due to applied forging load.

7. The degree of refinement increased with an increase in the working temperature from 300 to 400°C due to the decrease in the yield strength and consequent increase in bulk deformation of the material. However, an increase in the working temperature from 400 to 500°C led to coarsening of the silicon particles due to the faster rate of diffusion during forging.
8. The mechanical properties such as tensile strength and hardness of the Alloy A, B, and C enhanced significantly during bulk processing though impression and converging die forging. It may be attributed to the strong bonding between refined second phase particles which strengthens the alloys. In addition increase in dislocation density improves the hardness of the alloys. The alloy forged with the higher aspect ratio of 1.20 (35% deformation) and a reduction ratio of 2.0 (51% deformation) in impression and converging die respectively shows optimum mechanical properties in all composition of complex Al-Si alloy.
9. The hardness of the alloy increased as with the increase of the Si wt.%. It may be due as increased Si wt.% cause more dispersion of the Si particles in the matrix which decreases the volume fraction of the soft Al matrix. Therefore, applied load transferred from the soft Al matrix to hard Si particles and, thus increases the hardness of the Al-Si alloy.
10. Due to the presence of the needle-shaped Si particles and Fe-rich intermetallic phases led to brittle fracture during tensile testing of all alloys. The fractographic observations of the failed samples show a large area of cleavage facet also confirmed the brittle fracture in all composition of Al-Si alloy.
11. Wear resistance of the forged alloys was significantly improved as compared with as-cast alloy. It may be attributed to refinement in microstructural features and higher hardness the forged alloys as compared to the as-cast alloy. Wear resistance of the forged Alloy A with reduction ratio 2.0 was highest amongst

other Alloys B and C. It may be due higher hardness of the alloy reduces the penetration of counter hard asperities which in turn less wear of the pin surface.

12. SEM images of the worn surfaces reveal that adhesion and abrasion were the primary wear mechanisms in both as-cast and forged samples of Alloys A and B. While in Alloy C adhesion, abrasion and oxidation were the dominant wear mechanism. The severity of the worn surface increased at higher applied load and sliding distance in all alloys.

13. The AFM analysis depicts that surface roughness was minimum for the forged samples as compared to as cast alloy. It was attributed to low wear of the forged samples reduces the surface roughness.
14. From the above results, it is found that 400°C working temperature, 1.20 aspect ratio, and 2.0 reduction ratio are the optimum bulk processing conditions in terms of microstructural refinement, enhancement in mechanical properties and wear resistance of the forged Alloys A, B, and C.

It is expected that the result of these investigations will provide valuable insight into designing preforms and thus developing intricate forged products of the complex Al-Si alloys for typical applications in industries throughout the world.

## 7.2. Scope for the future work

Although the results of the present study provide valuable insight to understand the deformation behavior of the complex Al-Si alloys and its effect on the microstructural features, mechanical properties and wear characteristics during bulk processing. Still this, many works may be needed in the future to further investigate deformation behavior and enhanced the engineering properties of the material. Specifically:

- To investigate the deformation behavior of the complex Al-18Si-2.5Cu-0.6Fe, Al-11i-2.5Cu-0.6Fe, and Al-7.4Si-2.5Cu-0.6Fe alloys through bulk processing in plain strain conditions and its effect on the tribo-mechanical properties of the alloy.
- Computational analysis of the impression and converging die forging, and further optimize the processing conditions
- To analyze the corrosion behavior of the as-cast and forged alloys