CHAPTER – 7

CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH

7.1 CONCLUSIONS

The present investigation is an attempt to find the effect of different flow behaviour on the steady state creep stresses and creep rates in a thick-walled cylinder made of aluminum/aluminum alloy matrix reinforced with SiCp,w and subjected to high temperature/thermal gradient and pressure. The composite cylinder has either uniform or graded distribution of reinforcement. The cylinder has been assumed to operate at elevated temperature or under a radial thermal gradient in different segments of the study.

The study undertaken has led to the following conclusions;

1. The steady state radial, tangential and axial stresses, generally compressive, decreases on moving from the inner to outer radius of a thick-walled cylinder made of isotropic Al-SiCp and subjected to internal as well as external pressure. The nature of tangential stress becomes tensile near the outer radius of the cylinder.

2. The stress distributions in composite cylinder made of isotropic Al-SiCp do not vary significantly for various combinations of particle size, particle content and operating temperature, except for some sizable variation observed for tangential and axial stresses with varying content of SiCp.
3. The effective stress in composite (Al-SiCp) cylinder operating under internal and external pressures decreases on moving from the inner to outer radius. The effective stress increases and decreases respectively near the inner and outer radii with increase in particle size, decrease in particle content and increase in operating temperature. The effect of particle content on effective stress is much pronounced.

4. The effective, tangential and radial strain rates in a thick-walled cylinder made of isotropic Al-SiCp, subjected to both internal and external pressures decrease on moving from the inner to the outer radius. The strain rates in the composite cylinder could be reduced significantly by employing finer size of reinforcement, increasing the content of reinforcement and decreasing the operating temperature.

5. The optimum size and content of the reinforcement in a Al-SiCp composite cylinder, under a given set of operating conditions (i.e. operating pressures and temperature), can be obtained by performing simultaneous optimization of the cost of composite and the value of maximum strain rate in the composite cylinder for different combinations of size and content of the reinforcement within the specified range.

6. The radial stress (compressive) in the composite (Al-SiCp) cylinder decreases throughout in the presence of either thermal or particle gradient alone. The maximum variation in radial stress is noticed in the middle of composite cylinder. The simultaneous presence of both the gradients has reinforcing effect on radial stress.
7. The tangential stress in the composite (Al-SiCp) cylinder increases near the inner radius but decreases near the outer radius in the presence of either thermal or particle gradient alone. Under simultaneous presence of both the gradients, the tangential stress also experiences a reinforcing effect.

8. The effect of imposing thermal and particle gradients, either alone or simultaneously, on the axial and effective stresses in Al-SiCp cylinder is similar to that observed for tangential stress in the composite cylinder.

9. The steady state effective, tangential and radial strain rates in the composite (Al-SiCp) cylinder with linear particle gradient is lower over the entire radius when compared with cylinder having uniform distribution of particles, when both the cylinders have the same average amount of reinforcement. In the region near the inner radius the strain rates decrease due to higher particle content inspite of high effective stress whereas towards the outer radius the creep rates decrease due to lower effective stress inspite of lower particle content.

10. The steady state creep rates developed in a composite (Al-SiCp) cylinder having uniform distribution of SiCp and operating under a thermal gradient is lower over the entire radius, when compared with a similar cylinder but operating at a constant average temperature. Near the inner radius, lower temperature is able to reduce the creep rates inspite of higher effective stress but near the outer radius, the lower effective stress reduces the strain rates inspite of higher temperature.
11. The effective, tangential and radial strain rates in the composite (Al-SiCp) cylinder, operating under both thermal and particle gradients reduce further due to reinforcing effect of both the gradients.

12. By increasing particle gradient in the distribution of reinforcement, the tangential stress inhomogeneity in the composite (Al-SiCp) cylinder increases whereas axial stress inhomogeneity first decreases and then saturates with the increase in particle gradient beyond 18 vol%.

13. The strain rate inhomogeneity decreases with the increase in gradient in the distribution of SiCp reinforcement, which may reduce the chances of distortion of the FGM cylinder made of Al-SiCp.

14. The radial and tangential stresses in a transversely isotropic FGM cylinder made of 6061Al-SiCw and operating under internal pressure are marginally affected by the presence of anisotropy. The FGM cylinder having $\alpha <1$, exhibits a slight increase in radial stress in the middle of cylinder whereas the tangential stress exhibits a marginal decrease and increase respectively near the inner and outer radii, when compared to an isotropic FGM cylinder ($\alpha =1$). The effect of anisotropy on the radial and tangential stresses in FGM cylinder having $\alpha >1$ is opposite of that observed for FGM cylinder having $\alpha <1$.

15. Unlike radial and tangential stresses, the axial as well as effective stresses in the FGM cylinder made of 6061Al-SiCw subjected to internal pressure are significantly affected by the presence of anisotropy. The axial and effective stresses in FGM cylinder having $\alpha <1$ are significantly lower than that observed for isotropic FGM cylinder ($\alpha =1$). The effect observed in
FGM cylinder having $\alpha > 1$ is opposite to that observed for FGM cylinder having $\alpha < 1$.

16. The transversely isotropic FGM cylinder made of 6061Al-SiCw operating under internal pressure, having relatively higher strength in the tangential direction as compared to radial and axial directions (i.e. $\alpha < 1$), leads to significantly lower effective, tangential and radial strain rates over the entire radius.

17. With the increase in extent of anisotropy in the FGM cylinder made of 6061Al-SiCw, the inhomogeneity in creep stresses reduces but inhomogeneity in creep rates increases significantly. As a consequence, the chances of distortion in the FGM cylinder having $\alpha < 1$ are lower as compared to FGM cylinder with $\alpha > 1$.

18. The magnitude of creep stresses and creep rates in the FGM cylinder made of 6061Al-SiCw and subjected to both internal and external pressures are significantly lower than that observed in a similar FGM cylinder but subjected to internal pressure alone. However, the axial stress in FGM cylinder operating under the combined effect of internal and external pressures are slightly higher than that observed in FGM cylinder under internal pressure alone.

19. The simultaneous presence of both internal and external pressures in the FGM cylinder made of 6061Al-SiCw significantly reduces the inhomogeneity in axial stress and strain rates, when compared with FGM cylinder subjected to internal pressure alone.
20. The presence of residual stress in FGM cylinder made of 6061Al-SiCw has marginal effect on radial stress. However, the presence of residual stress leads to significant increase in tangential stress near the inner radius but significantly decreases the tangential stress towards the outer radius when compared to a similar FGM cylinder but without residual stress. In addition, the location of maxima observed for tangential stress shifts slightly towards the inner radius and its magnitude is also reduced when the FGM cylinder has thermal residual stress.

21. In the presence of residual stress, the compressive axial stress observed near the inner radius of FGM cylinder made of 6061Al-SiCw increases but the tensile axial stress observed near the outer radius decreases.

22. The presence of residual stress in the FGM cylinder made of 6061Al-SiCw leads to increase in effective stress, except for a slight decrease observed near the inner radius. The increase observed in effective stress increases with the increase in radial distance.

23. The presence of residual stress significantly modifies the distribution of strain rates in the FGM cylinder made of 6061Al-SiCw and results in minima somewhere in the middle of cylinder. The effective, tangential and radial strain rates in the FGM cylinder having residual stress are higher (except for some portion near the inner radius) than that observed in FGM cylinder without residual stress. The difference observed in strain rates between these FGM cylinders is more towards the outer radius.
7.2 SCOPE FOR FUTURE RESEARCH

The work present in this study may be extended in future on the following lines:

1. The creep response of the composite cylinder may be investigated by assuming several other forms reinforcement gradients.

2. The effect of imposing different kinds of thermal gradients may also be investigated on the steady state creep behaviour of the cylinder.

3. The analysis presented here may be extended for composite cylinder subjected to centrifugal loadings, axial force and combination of different internal and external pressures.

4. The analysis carried out in this work may be extended for creep laws based on other values of stress exponent \( i.e. n = 3 \) and 8, and its impact on the steady state creep stresses and creep rates may be investigated.

5. The analysis carried out for transversely isotropic FGM cylinder may be extended for orthotropic FGM cylinder.