CHAPTER 6

CONCLUSIONS AND SCOPE FOR FUTURE WORK

In this work, the evolutionary optimization techniques are used to find the optimal solutions considering all the objective functions of the multi-objective optimization problem. The performances of evolutionary techniques viz classical Genetic Algorithm, NSGA-I and NSGA-II are tested against the conventional Nelder-Mead nonlinear simplex technique.

6.1 Conclusions

From the study carried out, the following conclusions are drawn.

- The NSGA-II optimization technique is found to be the efficient among other optimization techniques implemented like NSGA-I, Genetic Algorithm and Nelder-Mead simplex techniques due to its strategies like fitness sharing and solution diversity preservation.

- The unconstrained objective function values Stage Efficiency, Stall Margin coefficient and Inlet Stage specific Area in NSGA-II technique compared to Nelder Mead simplex technique are more by
8.6%, 27.9% and 18.4% respectively. Also, when compared to Massardo [24], the values of Stage Efficiency, stall margin and Inlet stage specific Area obtained from NSGA-II technique are increased by 1.6%, 14.81% and 9.7% respectively. This is due to the capability of NSGA-II technique to produce high fitness solutions from a large population domain.

- The unconstrained objective function values i.e. Stage Efficiency, stall margin coefficient and Inlet stage specific Area, obtained from NSGA-II technique are increased compared to classical Genetic algorithm technique and are about 2.7%, 13.3% and 9.44% respectively. The NSGA-II technique with its solution diversity preserving strategy is found to be the better technique compared to classical Genetic Algorithm.

- The classical Genetic algorithm is better compared to Nelder-Mead simplex technique in minimizing the transformed objective function due to its capability to generate high fitness solution vectors using cross over and reproduction.

- For the constrained and unconstrained transformed objective functions, the objective function values for the set-1 decreased by 71% and 69.8% respectively compared to set-2. This is because of
the randomly attributed value of scalar weighing coefficient allocated to each of the objective functions.

- The value of constrained transformed objective function is reduced about 5% compared to the unconstrained. This is due to the penalty parameter value allocated in the constrained transformed objective function.

- The transformed objective function values obtained from Classical Genetic Algorithm are increased about 10% compared to Nelder-Mead simplex technique. Therefore, the genetic algorithm is found to be the better technique due to its capability to generate new improved solution vectors through selection, cross over and mutation.

- The non dominated unconstrained objective function values obtained from NSGA-II technique i.e stage efficiency, Inlet stage specific Area and Stall margin coefficient are increased by 0.8%, 1.32% and 11.2% respectively compared to NSGA-I technique. Also, when compared to Massardo [24], the percentage increase in stage efficiency, Inlet stage specific area and stall margin obtained from NSGA-II technique for unconstrained case are found to be 2.42%, 17.09% and 24.18% respectively. Similarly, the non-
dominated constrained objective function values obtained from
NSGA-II technique i.e stage efficiency, inlet stage specific area and
stall margin coefficient are increased by 2.27%, 2.19% and 7.03%
respectively compared to NSGA-I technique. It is due to the explicit
strategies implemented by NSGA-II technique like elite solution
preservation and solution diversity maintenance. However, when
compared to Massardo [24], the percentage decrease in stage
efficiency, Inlet stage specific area and stall margin obtained from
NSGA-II technique for constrained case are found to be 3.51%,
2.44% and 8.46% respectively. It is principally due to the influence
of centrifugal stress constraint and the value assigned to the
adaptive penalty function operator to handle constraint in NSGA-II
technique.

- The sensitivity of stage efficiency, stall margin coefficient and inlet
  stage specific area are observed as 11.5%, 40% and 35%
  respectively, due to change in mean diameter of axial flow
  compressor from 0.3 to 0.4 meters. The mean diameter showed
  significant influence on stage efficiency due to increase in the work
  input absorption of the compressor. Whereas, the mean diameter
  has a drastic influence on the stall margin coefficient because of
  increase in frontal area available for high mass flow rates of air
  and inlet stage specific area due to increase in blade height.
• The sensitivity of stage efficiency is 15.4% owing to variation in the flow coefficient from 0.2 to 0.6. The flow coefficient showed considerable improvement in stage efficiency because of increase in the angle of incidence of air.

• The sensitivity of stage efficiency and stall margin coefficient are observed as 9.42% and 40% respectively because of variation in shaft speed from 350 to 500 rpm. The shaft speed caused considerable impact on stage efficiency due to the increase in centrifugal stress and also showed a significant influence on stall margin coefficient due to increase in axial velocity and mass flow rate of air.

• The sensitivity of stall margin coefficient is 24.6% due to increase in air inlet angle from 0 to $\frac{\pi}{9}$ radians. The angle of incidence of air showed considerable influence on stall margin coefficient by reducing the stagnation pressure loss.

• The increase in stage efficiency is 5.74% because of increase in air inlet angle from 0 to $\frac{\pi}{9}$ radians. The air inlet angle made a
significant influence on stage efficiency by decreasing the stall inception probability.

- The sensitivity in inlet stage specific area is 30.36%, due to increase in hub-tip radius ratio from 0.4 to 0.9. The increase in hub-tip radius ratio reduced the net area available for the given mass flow rate and thereby showed significant influence on the inlet stage specific area.

- The transformed objective function value increased by 30% because of increase in mean diameter from 0.3 to 0.4 meters. The transformed objective function value decreased by 19.04% due to the increase in hub-tip radius ratio from 0.4 to 0.9. The design variables mean diameter and hub-tip radius ratio showed significant influence on the transformed objective function due to their predominant influence on inlet stage specific area and centrifugal stress, which form a significant portion of transformed objective function.

6.2 Scope for future work

The present problem can also be treated by considering the bending stress as a constraint to the multi objective optimization problem of axial
flow compressor inlet stage. The multi objective optimization problem can be optimized by considering the intermediate stages as well.

The present multi objective optimization problem of axial flow compressor inlet stage can be treated using the real coded Genetic Algorithms. The primary advantage with real coded genetic algorithms is that the gradual changes in functions with continuous variables can be exploited. Secondly the search speed can be greatly enhanced as there is no need for encoding and decoding of variables like that of binary coded genetic algorithms.

Also the multi objective optimization problem of axial flow compressor inlet stage can be experimented with hybrid evolutionary algorithms for optimum results. i.e.; the complimentary search tools are made to work in parallel with conventional algorithms for finding a global optimum with enhanced search capabilities.

The optimal trade-off solutions between the objective functions can be improvised using differential evolutionary techniques which can strike a balance between the required global optimum and the convergence requirements.