Chapter 5

Conclusions and future research scope

5.1 Conclusions

Owing the practical need to design different types of fins for dissipating excess heat from heat generating equipment in an economical way by maintaining longevity of fins, as well as subsequent research gap, detail procedures for design optimization of different types of fins under various conditions are presented in this thesis.

Six number of annular fin arrangements are investigated as multi-objective design optimization problems. In these six arrangements, both isolated fins and fin arrays are studied with three different types of fin profiles, namely rectangular fin with step change in thickness, linearly varying thickness and non-linearly varying thickness. In the operational conditions, all the fin arrangements are studied under steady-state one-dimensional heat transfer with constant base temperature and variable thermal conductivity along the radial directions of the fins.

In the context of optimization, fin arrangements are defined by various geometric parameters as the design variables of the optimization models, which mainly include fin outer radius, thicknesses at different locations, and number of fins or fin inter-spacing (in fin arrays only). In the stepped fins, thicknesses of the two steps along with the radius at the point of step change in thickness are taken, while the linearly varying thickness fin profile requires thicknesses at the base and tip of a fin. The non-linearly varying thickness fin profile is defined by a B-spline curve with its control points as design variables, from where the fin thicknesses at different locations along the radial direction of a fin are evaluated. After selecting design variables, six number of fin performance measuring parameters are considered for optimizing simultaneously in various combinations as the objective functions of the multi-objective optimization models. Out of these six parameters, maximization of the heat transfer rate, minimization the total fin volume and minimization of the induced thermal stress are treated as three primary objective functions. Additionally, maximization of the fin efficiency (surface efficiency in fin arrays), maximization of the fin effectiveness (augmentation factor in fin arrays) and minimization of the heat transfer surface area are also considered for further performance assessment of the fin arrangements.

As solution procedures, the fin volume and heat transfer surface area are computed through some standard numerical methods, while other objective functions are evaluated through the hybrid spline difference method (a highly accurate numerical method for solving differential equations). Then, the nondominated sorting genetic algorithm II (NSGA-II), a well-known and widely applied multi-objective stochastic optimizer, is employed for optimizing the considered objective functions in various combinations. In each case, the final outcome from NSGA-II is a Pareto front containing a set of trade-off solutions in terms of the investigated objective functions.

Performing numerical experimentation with some hypothetical data sets for the considered fin arrangements, the following major observations are made:

(i) In terms of the heat dissipation rate per unit volume, both isolated fins and fin arrays with non-linearly varying fin profiles are better than those with stepped fin profiles, while those with uniform fin profiles are the worst.

(ii) For the same heat dissipation rate, isolated fin with step change in thickness and uniform profile, both having no significant difference has higher efficiency. However, in case of fin arrays, fin array with uniform fin profile has the lowest efficiency. The heat dissipation rates from the non-linearly varying thickness fins and stepped fins for similar efficiencies have no significant difference.

(iii) The heat transfer rate from the isolated stepped fin is more sensitive to the fin outer radius, then to the fin radius at the point of step change, while the same is minimally influenced by the fin thickness. In the case of the fin array with stepped fins, the heat transfer rate is more sensitive to the fin outer radius, then to the number of fins in the fin array, while the same is marginally influenced by the fin thickness and radius at the point of step change.

(iv) In case of linearly varying isolated fins, both heat transfer rate and thermal stress are more sensitive to fin outer radius, then to the fin thickness at the base, while the same to the outer fin thickness is comparatively very less. On the other hand, in the fin array with linearly varying fin thickness, both heat transfer rate and thermal stress are highly sensitive to the fin outer radius. In the case of the heat transfer rate, the next sensitive design variable is the number of fins in the fin array, followed by the fin thickness at the base. The order of the design variables is opposite in the case of the thermal stress, i.e., the thermal stress is more sensitive to the fin thickness at the base than to the number of fins in the fin array.

5.2 Future research scope

Although a number of cases of optimization of annular isolated fins and fin arrays are investigated in this thesis, still ample scopes are there for carrying out future research on the theme, such as:

(i) In annular stepped fins, due to a large variation in temperature field in the region of step change, the thermal stress induced in that region is also very large. However, thermal stress in stepped fin is not analyzed in this thesis.

(ii) Heat transfer from a fin array by radiation may be studied, which is neglected in this thesis work.

(iii) The present study is limited to steady-state one-dimensional heat transfer along the radial direction of a fin. The work may be extended considering heat transfer under transient conditions.

(iv) The study may be extended to dehumidifying conditions also, which are not investigated in this work.