Chapter 2

Literature review

The literature review in this thesis has four subsections:

(i) Research works done on annular fins as a source of heat transfer enhancement.

(ii) Review on thermal stress related to an annular fins.

(iii) Research works done on optimization of isolated annular fins.

(iv) Research works done on annular fin array optimization.

A review on various research activities done on the analysis of annular fins as a source of heat transfer enhancement is given in the first subsection. As thermal stress influence the life of a fin, the various research on the thermal stress analysis in an annular fin is investigated under the second subsection. The third subsection carried a details study on optimization of isolated annular fin considering various objective functions. As single fin is rarely found, instead, for practical applications, an array of fins is used, hence, in the fourth subsection, the research activity done on optimization of annular fin array are explored.

2.1 Annular fins for heat transfer enhancement

A comprehensive review of the existing literature on extended surface heat transfer was carried out by Kraus et al. [34]. Adopting a semi-analytical approach, Kundu and Das [37] analyzed the performance of eccentric annular disk fins considering constant base temperature. The effectiveness of an annular rectangular fin on a pipe as a function of Biot number was presented by Look [56]. Considering two different materials, a model for temperature distribution and efficiency of annular fins was developed by Lalot et al. [47]. Using the homotopy perturbation method and considering temperature dependent thermal conductivity, Ganji et al. [24] studied the temperature distribution in an annular fin. An incremental differential quadrature method for analyzing two-dimensional nonlinear transient heat transfer characteristics of variable section annular fins was presented by Malekzadeh and Rahideh [57]. An inverse hyperbolic heat conduction model of an annular fin was studied by Lee et al. [52] using an inverse algorithm based on the conjugate gradient method and the discrepancy principle. Using an implicit central finite different method, Naphon [70] analyzed the heat transfer characteristics and efficiency of an annular fin under dry, fully and partially wet surface conditions.

Analyzing the performance of a stepped annular fin under fully and partially wet surface conditions, recently Kundu [35] reported that the rate of heat transfer per unit volume of a stepped annular fin is more in comparison with that of a concentric annular disc fin under the identical surface conditions. Further, thermal analysis and optimization of annular rectangular stepped fins were reported in [39, 42], in which also it was concluded that annular stepped fins provide higher heat dissipation rate per unit volume than annular disc fins.

2.2 Thermal stress in annular fins

Because of mathematical complexity as well as non-linearity of the problem, a very limited number of works concerning thermal stress on annular fins could be found in specialized literature [9, 19, 49, 93]. Employing Inverse Laplace transform equations along with complex contour integration and residue theorem, Wu [89] forwarded an analytical model for transient thermal stress distribution in an annular fin, in which a constant thermal conductivity for the fin material was considered. A work similar to that of Wu [89] was carried out by Lee et al. [50] using a hybrid numerical method involving Laplace transformation and finite difference schemes, in which also a constant thermal conductivity was considered for the fin material. In another work, the transient coupled thermo-elasticity of an annular fin was analyzed by Yang and Chu [91] with the application of Laplace transformation with respect to time and Fourier series techniques. Yu and Chen [92] employed Taylor transformation method in rectangular profiled convection-radiation annular fins to analyze thermal stress developed under variable thermal parameters. A problem similar to that of Yu and Chen [92] was investigated by Chiu and Chen [18] employing Adomian's double decomposition method under variable thermal conductivity for the fin material, in which it was found that the maximum radial and tangential thermal stresses occurred at a radial distance of 25% of the fin height and at the base of the fin respectively. An inverse analysis for predicting some unknown parameters in an annular fin subjected to the development of thermal stress was presented by Mallick and Das [60], in which a regular perturbation method was employed to evaluate the temperature distribution, which is then used to evaluate the stress field. Some other studies, employing inverse analysis for predicting unknown parameters in annular fins subjected to thermal stresses can be found in Chen et al. [15], Lee et al. [51] and Mallick et al. [61].

2.3 Optimization of isolated annular fin

With the application of Bessel functions, Brown [10] provided the optimum dimensions of constant thickness radial fins. Extending the work of Brown [10], Ullmann and Kalman [82] determined the efficiency along with the optimized dimensions of annular fins with rectangular, triangular, parabolic and hyperbolic profiles under constant heat transfer coefficient, in which the parabolic profile was outperforming other profiles. Taking constant thermal conductivity of fin material and neglecting heat transfer by radiation, Arslanturk [3] proposed an analytical approach for constant volume optimization to maximize the heat transfer rate in rectangular profile annular fins with thermally non-symmetric convective boundary conditions. Yu and Chen [93] presented an analytical method, based on differential transformation, for thermal analysis and constant volume optimization of a rectangular profile annular fin with variable thermal conductivity and variable convective heat transfer coefficient. Kang and Look [31] derived another analytical method for optimizing a convective and radiating rectangular annular fin under thermally asymmetric conditions. A comprehensive scheme using calculus-based technique was developed by Kundu and Das [40] for optimizing elliptic fins. Malekzadeh et al. [59] combined the differential quadrature method and the golden section search method for optimizing non-symmetric convective-radiative annular fins by maximizing the heat dissipation for a given volume. The performance and optimization issues of single annular fins, related to simultaneous heat and mass transfers under various dehumidifying conditions, were taken up by many researchers, including Sharqawy and Zubair [79] and Kundu [35]. Under the consideration of a fixed height for a rectangular profile annular fin with fluid in the pipe, Kang [29] presented an optimization procedure based on a variable separation method. An optimization strategy for eccentric annular disc fins was put forward by Kundu and Das [38] making an observation that eccentric annular disc fins, in comparison to concentric annular disc fins, can dissipate more heat for a given volume with space restriction on one side of the tube. Some other studies, optimizing annular fins with specified geometry, can be found in the works of Laor and Kalman [48], Kang and Look [30], Kang and Look [32], Nemati and

Samivand [71], Nagarani et al. [69], Kundu et al. [44], and Pashah et al. [74].

2.4 Optimization of annular fin array

Heat transfer by convection occurs from both surfaces of a fin as well as from the fin inter-spacing [5, 45]. There could be two main approaches for optimizing a fin array. In the first approach, the optimized fin array may be considered to be consisted of a number of individual fins each optimized separately in isolation. The second approach is to optimize the individual fins and the fin inter-spacing by considering the entire fin array and its supporting structures as a whole. Since the thermal conditions of individual fins will differ when placed in an array, the first approach would result in an inefficient fin array configuration. Hence, the second approach is widely applied for advanced technological solutions, as for example, in the thermal control of electronic equipment [12]. Only a few works on the optimization of a fin array could be found in specialized literature, most of which studied a fin array consisting of fins of constant cross-sectional area [8, 45]. However, for better utilization of the fin material, the thickness of a fin should decrease gradually in the outward direction of the fin [36]. Other studies were limited only to the maximization of the heat transfer rate by considering either a predefined fixed volume [36, 43] or a fixed total height of the fin assembly [41].

2.5 Motivation for the present research

From the literature review performed, it can be easily understood that although analysis and optimization of annular fin and fin array are done, there is still lot of scope to optimized annular fin and its array under multiple objective functions. Also, to solve the optimization problem, various classical methods have been used, which may fail to give optimal results due to large number of constraints involved. From the research works described in Sections 2.3 and 2.4 it is found that although single objective optimization of annular fin and its array is done either considering a fixed volume or a fixed heat transfer rate, the work on multi objective optimization of annular fin and its array is very limited. In fact multi-objective optimization of annular step fin and its array under various objective functions has never been done. Although thermal stress play a important role in fin material failure, researcher have ignored the optimization of annular fin considering the optimization of thermal stress as one of the objective. It is for the first time, the optimization of thermal stress in annular fin and its array has been taken up in this study.

Though the attachment of multiple fins to a heat exchanger is expected to increase the heat transfer rate by increasing the total heat transfer surface area, but accommodation of excess number of fins by reducing fin inter-spacing below a critical value may even decrease the heat transfer rate by blocking air flow.

Hence, scope is there for optimizing the heat transfer rate, fin volume as well as the thermal stress by modifying fin geometry and fin inter-spacing within their allowable limits. However, no such work optimizing both heat transfer rate and fin volume in annular step fins or heat transfer rate and thermal stress in annular fins could not be found in literature.

The thesis emphasizes on the optimization of annular fin under different objective functions. The idea is to generate a multi-objective optimization problem for optimization of annular fin and its array. Focus is given to the implementation of a multi objective optimization algorithm, i.e., non-dominated sorting genetic algorithm II (NSGA-II) in optimizing fin and its array under multiple objective functions.