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Research Paper

Thermal Systems: Design, Simulation and Optimization

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ABSTRACT: *Design of thermal systems is no longer primarily an art and experience but it has now shifted to a rigorous optimization procedure, the commercial software tools are being routinely used to the best possible design under the conditions at hand. Thermal system design and analysis continues to develop. The number of workers is growing, technical papers appear in greater numbers, and new textbooks are being written. Many concepts like use of information flow diagrams to simplify the simulation procedure, novel optimization methods suitable for thermal system simulation, etc. have been developed. Researchers have developed detailed simulation procedures for equipment used in refrigeration systems. Also thermal power plants and novel desiccant-based cooling systems have been developed over the years. This paper discusses briefly the procedures for thermal systems design, simulation and optimization developed over the decades.*
KEYWORDS: *Thermal Systems, Design, Simulation, Analysis, Processes, Optimization.*

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I. INTRODUCTION

At present the design of thermal systems are not done by thumb rules based largely on experience. Authoritative handbooks are now routinely used to design safe and functional systems. Important design parameters are obtained from these handbooks. Professionally the design, among many probable alternatives, has to be optimized techno-economically. The ideal design would be the evaluated optimum from cost, weight, floor area, efficiency, and performance point of view. Even arriving at a workable design of a thermal system may turn out to be a herculean task. Sometimes, even otherwise an optimum design may not be a practical solution or aesthetically good one. However, in modern times, the possibility of doing high speed computation through computers has made computer-aided optimum thermal systems design commercially viable. A "feasible thermal system design may not be the optimal design. This necessitates use of mathematical/numerical optimization techniques to generate alternative designs which are likely to be "better" than the initial design. This requires computer-based system and comprehensive simulation procedures to predict the performance of each component of the system and a methodology to integrate these procedures in tune with their actual interconnection in the system. A comprehensive computer program would give optimal design of a thermal system which would essentially use an optimization algorithm to maximize/minimize the objective function subject to the constraints. This provides the required thermal performance without compromising on other non-thermal performance measures like long life, safety, permissible wear and tear, noise, etc. It should be possible to assess the influence of various operating parameters. Most thermal systems rarely operate on the design conditions, and the "off-design" performance must have good control strategies to ensure safe and optimal operation even under off-design operating conditions. The thermal systems design, simulation and optimization are discussed in this paper.

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II. MATHEMATICAL BACKGROUND AND REVIEW OF FUNDAMENTALS

Strong mathematical background and commence in fundamentals are necessary even for very basic thermal systems design, simulation and optimization. There has to be a good knowledge in linear and non-linear algebraic equations, curve fitting, differential equations, integral transforms like Laplace Transform, engineering economics, uncertainty analysis, numerical tools and computer programming. Good knowledge in thermodynamics, heat transfer and fluid flow, mass and concentration transfer is a pre-requisite for thermal systems design, simulation and optimization.

III. MODELLING OF THERMAL EQUIPMENT AND SYSTEM SIMULATION

Thermal equipment may be heat exchangers of many types like parallel flow heat exchangers, counterflow heat exchangers, cross flow heat exchangers, heat exchangers equipped with enhancement techniques, tube and tube heat exchangers, tube and shell heat exchangers, single and multiple pass heat exchangers and other different types. There can be heat and mass exchangers, reciprocating and rotating devices, thermoelectric and other applications. Thermal equipment have to be modeled properly. Information flow diagram is important. Solution methodology can be of different types as per necessity. There has to be off-design performance prediction. Case-studies of system simulation like industrial refrigeration plant, combined cycle power plant, liquid desiccant based air-conditioning system (LDAC) throw valuable insight and often does give important information.

IV. OPTIMUM DESIGN, OPTIMIZATION TECHNIQUES AND CASE STUDIES IN OPTIMUM DESIGN, DYNAMIC RESPONSE OF THERMAL SYSTEMS, ADDITIONAL CONSIDERATIONS IN THERMAL DESIGN

The general formulation of an optimum thermal system design problem is necessary. The components must be optimally designed by analytical and numerical methods. Optimum design of thermal systems must satisfy laws of thermodynamics. The dynamic response of first order thermal systems, higher order systems, transportation lag, principle of superposition, control system analysis, dynamics of distributed systems are important topics to be mastered and dealt with successfully. There are additional considerations in thermal systems design like erosion, corrosion, vibration and noise, stochasticity, part-load operation, environment, multiplicity in objectives, commercial software, etc.

V. CONCLUSION

Aspects of design, simulation and optimization of thermal systems have been discussed very briefly in this paper. Reference list below gives the sources from which detailed important information can be drawn.

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