Chapter Two

Literature Review

2.1 INTRODUCTION

In 1996, Badescu and Andresen proposedthat finite-time thermodynamics (F.T.T.) can becomplemented with some probabilistic conceptsallowing a more accurate description of theperformance indicators of a power system. Theseauthors studied a continuous flow tube reactor whichsupplies heat to an engine from a chemical reactionwith linear kinetics. In general, typical FTT-modelsof thermal cycles are worked in steady state and onlyone cycle is taken as representative of all the othercycles pertaining to a sequence of them. In a typicalinternal combustion engine, several thousands ofcycles are performed in a minute and there existtheoretical and experimental reasons to expectimportant variations from one cycle to the next.

2.2 HISTORICAL BACKGROUND

Finite-time thermodynamics was ‘invented’ in 1975 by R. S. Berry, P. Salamon, and B. Andersen as a consequence ofthe first world oil crisis. It simply dawned on us that all the existing criteria of merit were based on reversibleprocesses and therefore were totally unrealistic for most real processes. That made an evaluation of the potentialfor improvement, of minimizing the losses, for a given process quite difficult.

Finite-time thermodynamics is coming of age. A child ofthe 1973 oil crisis, it was conceived in 1975, and the firstpublication on this topic appeared in 1977.

2.3 LITERATURE REVIEW

Lingen Chen *et.al*(2000) definedthe power density as the ratio of power output to maximum specific volume in the cycleis taken as the objective for performance analysis of an endoreversible closed Joule-Brayton cycle coupledto variable temperature heat reservoirs in the viewpoint of finite time thermodynamics or entropy generation minimization. The analytical formulae about the relation between power density and pressure ratio are derived with the heat resistance losses in the hot and cold side heat exchangers.The obtained by using maximum power criterion. The influences of somedesign parameter on the maximum power density are provided by numerical examples, and the advantages anddisadvantages of maximum power density design are analyzed. The power plant which designedwith maximum power density leads to a higher efficiency and smaller size. When the heat transferis effected ideally and the thermal capacity rates of the two heat reservoir are infinite.

YasinUst*et.al*(2005) worked onperformance optimization based on a new ecological criterion called ecological coefficient of performance (ECOP) had been presented for irreversible Joule-Brayton heat engine. The considered model was included irreversibilities due to finite rate heat transfer, heat leakage and internal dissipations. The (ECOP) objective function was defined as the ratio of power output to the loss rate of availability. The optimal performance and design parameters at maximum (ECOP) conditions were obtained analytically. The effects of major parameters on the general and optimal ecological performances had been investigated. The obtained results based on ECOP criterion were compared with an alternative ecological objective function defined in the literature and the maximum power output conditions, in terms of entropy generation rate, thermal efficiency and power output.

T. Yilmaz (2007) found that the proper optimization criteria to be chosen for the optimum design of heat engines may differ depending on their purposes and working conditions. If the heat engine design was done not to obtain maximum work or power, but to have maximum benefit from energy, then the design objective is to get maximum efficiency. In this study, a new performance analysis was applied to a reversible Joule–Brayton cycle based on a new criterion which was proposed for all kind of heat engines. The proposed criterion, called efficient power, was defined as the multiplication of power by efficiency. Therefore, this criterion considers not only the power output but also the cycle efficiency. Maximizing the efficient power function gives a compromise between power and efficiency. The results showed that the design parameters at maximum efficient power (MEP) conditions lead to more efficient engines than that at the maximum power conditions and that the (MEP) criterion may have a significant power advantage compared to the maximum power density criterion.

Y.Ge*et.al* (2008) study the performance of an irreversible air-standard reciprocating simple Joule-Brayton cycle with heat transfer loss, friction-like term loss and variable specific heats of working fluid was analysed by using finite-time thermodynamics. The relationships between the power output and the compression ratio, between the thermal efficiency and the compression ratio, as well as the optimal relationship between the power output and the efficiency of the cycle were derived by detailed numerical examples. Moreover, the effects of variable specific heats of the working fluid and the friction-like term loss on the irreversible cycle performance were analysed. The results show that the effects of variable specific heats of the working fluid and friction-like term loss on the irreversible cycle performance were obvious, and they should be considered in practical cycle analysis. The results obtained in this paper may provide guidelines for the design of practical reciprocating Joule-Brayton engines.

Yanlin GE *et.al* (2008) analyzed the Performance of an air standard reciprocating Joule-Brayton cycle with heat transfer loss and variable specific heats of working fluid by using finite-time thermodynamics. The relations between the work output and the compression ratio, between the thermal efficiency and the compression ratio, as well as the optimal relation between work output and the efficiency of the cycle were derived by detailed numerical examples. Moreover, they analyzed the effects of heat transfer loss and variable specific heats of working fluid on the cycle performance. The results showed that the effects of heat transfer loss and variable specific heats of working fluid on the cycle performance are obvious, and they should be considered in practice cycle analysis. The results obtained in their paper may provide guidance for the design of practice internal combustion engines.

Jiang Qin (2009) conduct a study on a closed Joule-Brayton cycle thermal management system was proposed for a regeneratively cooled scramjet to reduce the hydrogen fuel flow for cooling, through converting part of the heat from fuel to other forms of energy to decrease the heat that must be taken away by hydrogen fuel. Fuel heat sink (cooling capacity) was thus indirectly increased. Instead of carrying excess fuel for cooling or seeking for any new coolant, the fuel flow for cooling was reduced, and fuel onboard was adequate to satisfy the cooling requirement for the whole hypersonic vehicle. A parametric study of an irreversible closed Brayton cycle thermal management system for scramjet had been performed with external as well as internal irreversibilities. It was known through performance analyses that closed Joule-Brayton cycle thermal management system had excellent potential performance over conventional regenerative cooling, due to the reduction in fuel flow for cooling and additional power output.

Ebrahimi (2010) analyzedthe performance of an air standard Atkinson cycle using finite time thermodynamics.In the endoreversible cycle model the linear relation between the specific heat ratio of the working fluid and its temperature and the heat transfer loss were considered. The relation between the network output, the thermal efficiency and compression ratio were indicated by numerical examples. Moreover the effects of variable specific heats of the working fluid on the endoreversible cycle performance the results show that the effect of the temperature dependent specific heat of the working fluid on the endoreversible cycle performance is significant. The conclusions of the investigation are of importance when considering the designs of actual Atkinson engines.

J.Liu (2011) conduct a study on a general cycle model of a class of typical irreversible heat engines with temperature-dependent heat capacities of the working substance is established. The expressions for work output and efficiency of the heat engines are derived. The influence of variable heat capacities of the working substance, heat leak losses, compression and expansion efficiencies and other parameters on the optimal performance of the cycle is investigated. The optimum criteria of some important parameters are obtained and the optimal operating regions of the heat engines are determined. The optimum performance of several typical heat engines is directly derived. The results obtained may provide some theoretical guidance for the performance improvement and optimal design of real heat engines.

K. Patodi and G. Maheshwari(2012) took the efficient power, defined as the product of the power output and efficiency, as the objective for performance analysis and optimization of an ideal air-standard Atkinson cycle with variable specific heats of the working fluid. Performance analysis carried out in the viewpoint of finite-time thermodynamics or entropy generation minimization. Results obtained were compared with those obtained by using the maximum power (MP) and MP density (MPD) criteria, and the advantages and disadvantages of a maximum efficient power (MEP) design were analyzed. The result showed that the engine designs at (MEP) conditions have an advantage of smaller size over those designed at (MP) conditions and are more efficient than those designed at (MP) and (MPD) conditions. Moreover, engines designed at (MEP) conditions require lesser pressure ratio than those designed at (MPD) conditions

R.Kumar*et.al* (2013) analyzed the efficient power of Joule-Brayton heat engine with friction based on the first and second law of thermodynamics. The efficient power isthe product of Joule-Brayton power output and Brayton efficiency. The proposed method considers both Brayton power output andJoule-Brayton efficiency. The work done against friction was also included intothe analysis of Joule-Brayton heat engine. The efficient power of Joule-Brayton heat engine with friction was obtained and results are recovered known from finite time thermodynamics. Joule-Brayton heat engine with friction gives realistic prediction of engine efficiency and engine power than does the isentropic Joule-Brayton heat engine without friction.

Al-Sood*et.al* (2013) has developed a general mathematical model to specify the performance of an irreversible gas turbine Joule-Brayton cycle incorporating two-stage compressor, two-stage gas turbine, intercooler, reheater, and regenerator with irreversibilities due to finite heat transfer rates and pressure drops. Ranges of operating parameters resulting in optimum performance (i.e.,η_I ≥38≥η_{II} ≥60%, ECOP≥1.65,x_{loss} ≤0.150 MJ/kg, BWR≤0.525,W_{net}≥0.300 MJ/kg, andq_{add}≤0.470 MJ/kg) were determined and discussed using the Monte Carlo method. These operating ranges are minimum cycle temperature ranges between 302 and 315 K, maximum cycle temperature ranges between 1,320 and 1,360 K, maximum cycle pressure ranges between 1.449 and 2.830 MPa, and conductance of the heat exchanger ranges between 20.7 and 29.6 kW/K. Exclusive effect of each of the operating parameters on each of the performance parameters was mathematically given in a general formulation that is applicable regardless of the values of the rest of the operating parameters and under any condition of operation of the cycle.

Gang Cheng*et.al* (2014) study the Performance analysis of a real power cycle has been performed using finite-time thermodynamics. The analytical formulae about the relations between power output and pressure ratio, and between efficiency and pressure ratio of a real closed regenerated Brayton cycle coupled to variable-temperature heat reservoirs are derived. In the analysis, the irreversibilitiesinvolve the heat resistance losses in the hot and cold side heat exchangers and the regenerator, the irreversible (non-isentropic) expansion and compression losses in the turbine and compressor, and the pressure drop loss in the pipe and system. The optimalperformance characteristics of the cycle may be obtained by optimizing the distribution of heat conductance or heat-transfer surface areas among two heat exchangers and regenerator, and the matching between working fluid and heat reservoirs. For the specified heat reservoir conditions, the power output is dependent on the effectiveness of the regenerator, and there exists an optimal matching among the effectiveness's of the hot and coldside heat exchangers and the regenerator. The influences of the effectiveness of the regenerator, the effectiveness of the hot and coldside heat exchangers, the efficiencies of the turbine and compressor, the pressure recovery coefficient and the inlet temperature ratio of the heat reservoirs on the power output and efficiency of the cycle are analyzed by detailed numerical examples.

RajeshArora*et.al* (2015) Made analysis for efficient power optimization of Joule-Brayton heat engine with variable specific heat of the working fluid is from the view of finite time thermodynamics. The proposed method considered not only the power output but also the engine efficiency. Optimizing the efficient power gave a compromise between power and engine efficiency. Results obtained are compared with those obtained by using the maximum power (MP) and maximum power density (MPD) conditions. The results showed that the engine designed at maximum efficient power (MEP) criterionis more efficient as compared with those designed at maximum power and maximum power density conditions. The system analysis was done with variable specific heat parameter due to which its performance is comparable to the real systems. Moreover, engine designed at maximum efficient power criterion requires lesser pressure ratio over those designed at maximum power density conditions. they found that Brayton heat engine with variable specific heat of the working fluid gives realistic prediction of engine efficiency and engine power than does the isentropic Brayton heat engine with constant specific heat.