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RELATIVE EFFECT OF PRESSURE LOSSES AND INEFFICIENCIES OF TURBOMACHINES ON THE PERFORMANCE OF THE HEAT-EXCHANGE GAS TURBINE CYCLE

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Abstract—The gas turbine engine is known to be relatively more sensitive to pressure losses and inefficiencies of components than any other engine. Therefore, a quantitative evaluation of the resulting performance is necessary. In this paper, a heat-exchange cycle, which is widely used due to its higher efficiency, is considered. Performance, including work and thermal efficiency, in addition to air mass flow, is evaluated over a wide range of operating conditions, namely, compressor pressure ratio, and efficiency plus turbine efficiency. A specially designed computer program was used. The analysis resulted in a set of curves which help the designer to easily estimate the percentage change in performance and engine cost relative to the ideal cycle over a wide range of operating conditions. Copyright © 1996 Elsevier Science Ltd

Keywords—Gas turbines; cycle analysis; heat-exchange cycle.

NOMENCLATURE

C_{pa} specific heat at constant pressure for air (kJ/kg.K)
C_{pg} specific heat at constant pressure for gas (kJ/kg.K)
f fuel–air ratio
H_c enthalpy of combustion (kJ/kg)
m mass flow rate (kg/s)
n polytropic index
p absolute pressure (bar)
P_{01} inlet pressure (bar)
r_c compressor pressure ratio (bar)
T_{03} turbine inlet temperature (K)
WL lost work (kJ/kg)
WI ideal work (kJ/kg)
W actual work (kJ/kg)

Greek letters
Δp total pressure drop in combustion chamber and air side of heat exchanger (bar)
Δp_{hg} pressure drop in the gas side of heat exchanger (bar)
ϵ heat exchanger effectiveness
γ ratio of specific heats
η thermal efficiency (%)
η_c compressor polytropic efficiency (%)
η_t turbine polytropic efficiency (%)

Subscripts
a air
b combustion chamber
c compressor
g gas
o stagnation value
1,2,3 station numbers along the cycle

INTRODUCTION

There is a general agreement that gas turbines will play an increasingly important role for both base load and peaking generation [1]. Some actions aiming at cutting pollution may see gas turbine power substituting steam power plants.

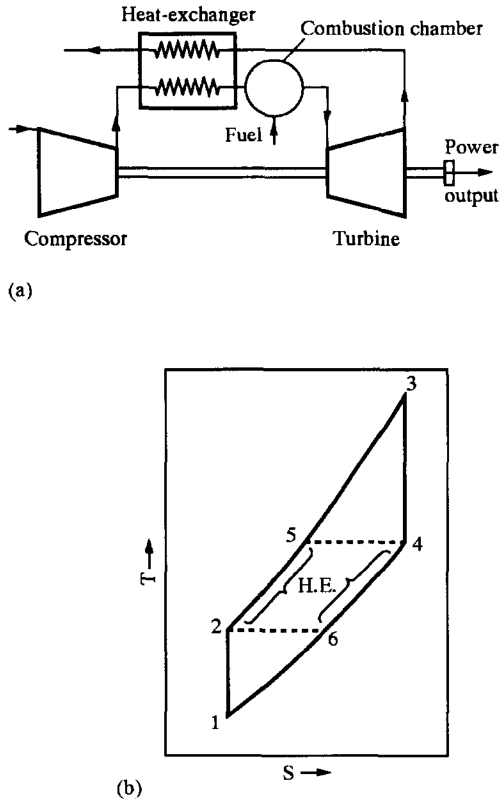

Fig. 1. Single-shaft open cycle gas turbine with heat exchanger.

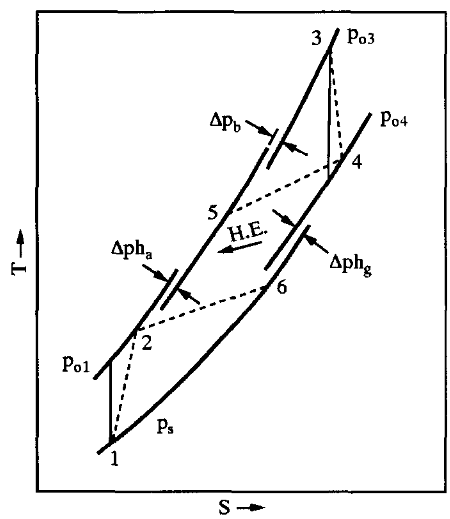

Fig. 2. Pressure losses.

In the simple gas turbine cycle, the compressor may require 40–80% of the turbine work. This is particularly important when the actual cycle is considered, because the effect of losses is to decrease the turbine pressure ratio relative to the compressor pressure ratio and thus reduce the

Table 1. Design point performance results

	T_{02}	T_{04}	T_{05}	P_{03}	P_{04}	P_{05}	$W_{t,c}$	W_t	W	f	m	η
System I	472.33	871.90	871.90	5	1	5	178.8	498.44	319.64	0.0142	62.6	0.53
System II	472.33	928.57	808.80	4.737	1.2	4.834	178.8	468.44	289.54	0.1582	69.06	0.43
System III	496.67	871.90	871.90	5	1	5	203.73	498.53	294.80	0.0144	67.84	0.50
System IV	472.33	927.5	927.5	5	1	5	178.8	433.1	254.32	0.01277	78.6	0.46