Ain Shams University

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Theoretical Study for Turbocharged four-stroke Internal Combustion Engine

Thesis submitted in the partial fulfillment for the degree of Master of science in Mechanical Engineering (Energy)

By

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PREFACE

This thesis is submitted to Ain Shams University for the degree of Master of science in Mechanical Power Engineering.

Part of the work in this thesis has been carried out by the author using the computer facility in the computer division of the Military Technical Institute.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

بسم الله الرحمن الرحيم

ABSTRACT

This study presents a theoretical calculation for a 4-stroke, turbocharged, compression ignition engine cycle. A mathematical model is established to simulate all the processes that take place inside the engine cylinder, at different loads and speeds. The mathematical calculation involves, some realistic assumptions which are considered to simplify the complicated processes inside the engine cylinder under supercharging conditions. The mathematical model includes solution for the compressor, and the engine. A computer program is developed capable of solving the mathematical model, under various running conditions (compressor pressure ratio, inlet air temperature, fuel-air ratio, engine speed, injection advance angle .... etc.). The results of the computation revealed the following:-

- The predicted engine performance has the same trends as compared with the experimental results.
- The accuracy of the predicted results is about 80% which can be improved by refinement of the computer program.

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CONTENTS

NOMENCLATURE

$\dot{m}$	=	mas flowrate	Kg/s
T	=	Temperature	°K
P	=	Pressure	N/m^2
N	=	Speed	r.p.m
C	=	Velocity	m /s
E	=	Total internal energy	Joule
b	=	number of molecules	
V	=	Volume	m^3
n	=	$\frac{\text{connecting rod}}{\text{crank radius}}$	
S	=	stroke	m
D	=	bore	m
R	=	universal gas constant	Joule/ Kg-mol °K
C_v	=	specific heat at constant volume	Joule/ Kg -mol °K
C_p	=	" " " " pressure	Joule/Kg-mol °K
DMf	=	mass of burnt fuel	Kg
dw	=	Piston work	Joule
q_{vs}	=	Lower molar colorific value	Joule / Kg -mol
h	=	enthalpy	Joule
P_I	=	Intake pressure	N/m^2
T_I	=	Intake temperature	°K
H_I	=	enthalpy of the inlet gases	Joule
P_E	=	exhaust pressure	N/m^2
T_E	=	exhaust temperature	°K

h_E	=	enthalpy of the exhaust gases	Joule
m_M	=	mass of manifold gases	Kg
P_m	=	manifold pressure	N/m^2
T_m	=	manifold temperature	°K
U	=	internal energy	Joule
Q	=	heat transfer from or to the cylinder walls	Joule
A	=	area	m2
X	=	isentropic index	
M	=	mass	Kg
F	=	equivelence ratio	
T	=	ambient temperature	°K
P	=	atmospheric pressure	N/m^2
BDC	=	Bottom dead centre	
TDC	=	top dead centre	
EO	=	exhaust valve opens	
EC	=	exhaust valve closes	
IO	=	intake valve opens	
IE	=	intake valve closes	
FE	=	The accuracy	
ENT	=	internal energy of the cylinder contents.	Joule
R_e	=	Reynold's number.	
K	=	thermal conductivily	Joule/ m °K s
C_d	=	discharge coefficient.	
K_v	=	valve lift / valve diameter.	
P_b	=	brake mean effective pressure	bar

g_b	=	brake specific fuel consumption	g/Kwh
T_b	=	brake torque	Nm
B_p	=	brake power	KW
C_{TS}	=	isentropic speed	m /s

CHAPTER 1

INTRODUCTION

The energy crisis,triggered in October 1973 by the Arab oil producers, has made it clearer than before that fuel from crude oil will not be at our disposal forever. The necessary demands for greater environmental protection set new problems for the internal combustion engine and make its life more difficult than before. Nevertheless, predictions of the approaching disappearance of the internal combustion engine are premature, as the engine cannot be readily replaced, especially because of its low first cost and economic operation and because of its versatility and adaptability.[1]

An internal combustion engine converts some of the energy released during combustion process to useful work,however there is an upper thermodynamic limit to the efficiency of conversion and a practical limit to the degree of success in approaching the thermodynamic efficiency.

The power produced by an engine is approximately proportional to the quantity of fuel burnt, and the latter is controlled by the air supplied to the engine.

In order to increase the air supply an external air source is required. When this is provided, the engine is said to be supercharged. For a given output power, the advantages of supercharging are :

1 - Reduced space requirements (few cylinders, shorter engine)

2 - Lower weight, better specific weight.

3 - Better efficiency with exhaust-turbocharging (flatter fuel consumpion characteristics).

4 - Lower cost per unit output, in particular for larger engines.

5 - Smaller radiator ; less heat per cent is lost than in naturally aspirated engines.

6 - The exhaust noise is reduced by the exhaust turbine.

7 - Less derating with reduced ambient density.

8 - Lower emission with certain controlled combustion processes.

The disadvantages of supercharging are:

1 - Greater mechanical and thermal loads.

2 - Inferior torque characteristics. }only with exhaust

3 - Poor acceleration. }turbo charging to }high boost ratios

4 - High smoke level during starting .

1.1 - Methods of supercharging : -

There are basically three methods [2]

1.1.1 - Using the gasdynamic (Pulse system) .

The use of gasdynamic means the use of wave action, effects in the intake and exhaust manifolds. There are two methods for such use:-

a) Manifold tuning

b) Comprex (A device in which the effect of wave action between hot and cold interfaces is used to raise the air pressure).

1.1.2 - Mechanical Supercharging.

In this method a separate pump is provided to supply air to the engine. The air pump may be driven from the crankshaft or connecting rod or by separate electric motor.

1.1.3 - Turbocharging.

In this method the compressor is driven using some of the energy available in the exhaust gases. The gas is expanded in a gas turbine which drives the compressor.

1.2 - Turbocharger

A turbocharger comprises a gas turbine and a compressor. The gas turbines in small turbochargers are normally radial turbines, whilst in a large turbocharger they are always single-stage axial turbines. The compressors are always single stage centrifugal compressors with radial impellers and vaneless diffusers. The characteristics of the two types of turbine are shown in Figs1.1 (a)and 1.1(b)and figs 1.2(a) and 1.2 (b) respectively. The characteristics of a typical centrifugal compressor are shown in fig 1.3.

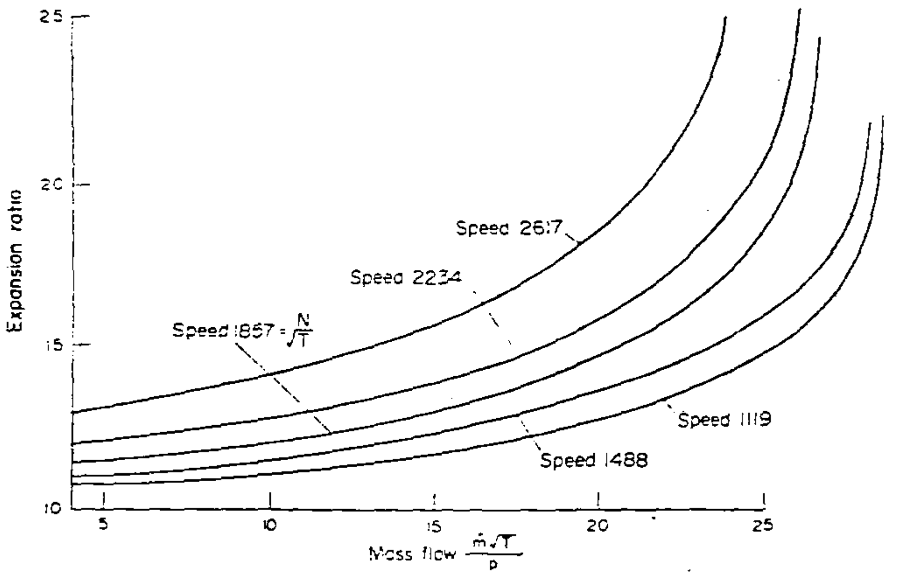

Fig 1.1 (a) Radial turbine mass flow characteristics. $\dot{m}$, Flow rate; T,inlet temperature; P,initial pressure;N, rotor r.p.m. [2]

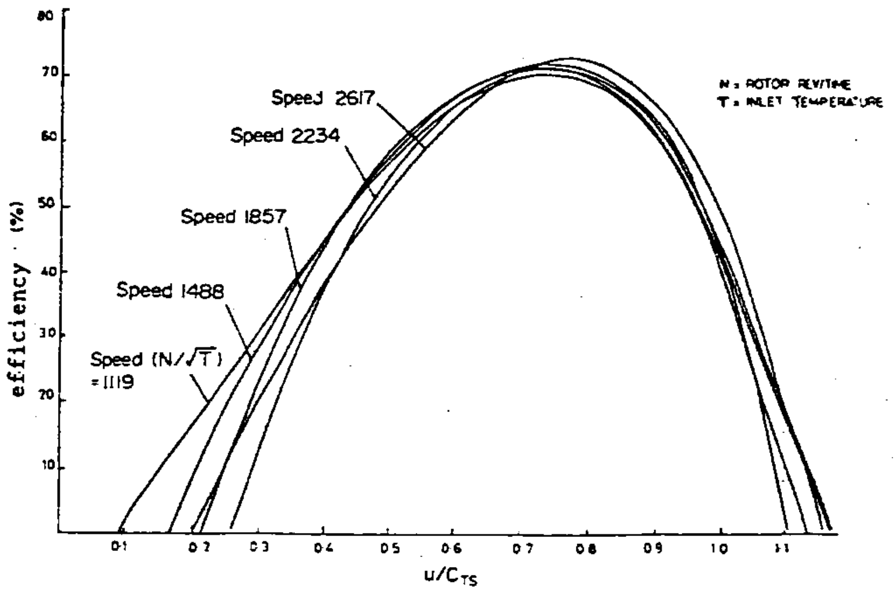

Fig 1.1 (b) Radial turbine efficiency. N,rotor r.p.m. T,inlet temperature. [2]

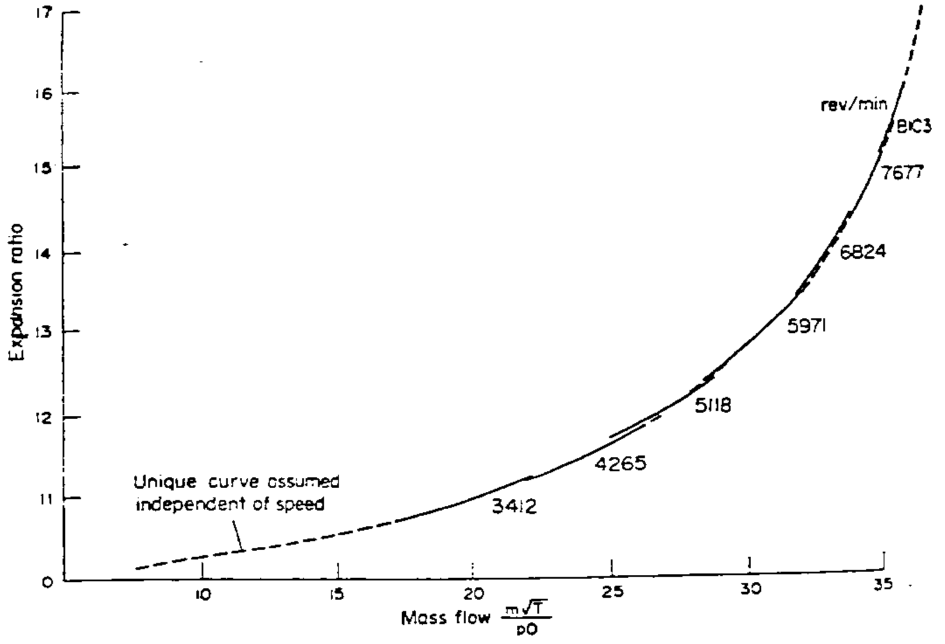

Fig 1.2 (a) Axial turbine characteristics. [2]

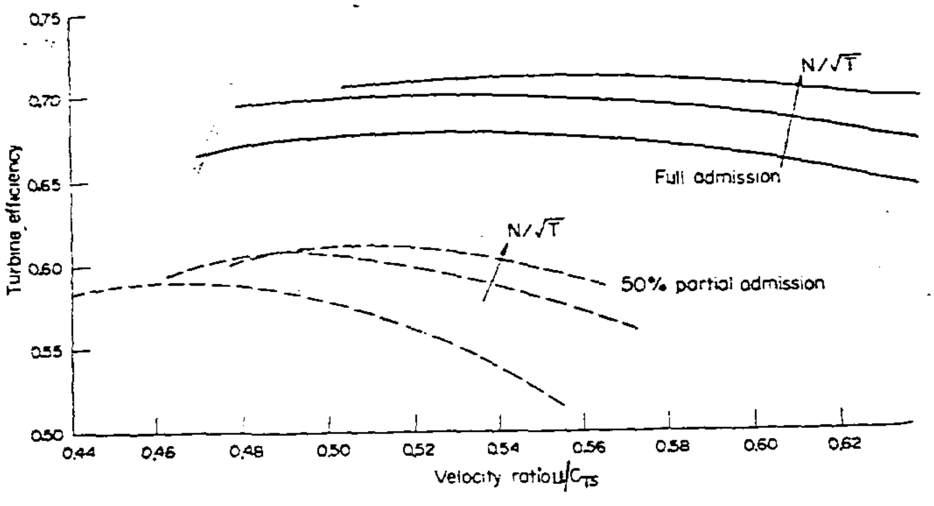

Fig 1.2 (b) Axial turbine efficiency. [2]

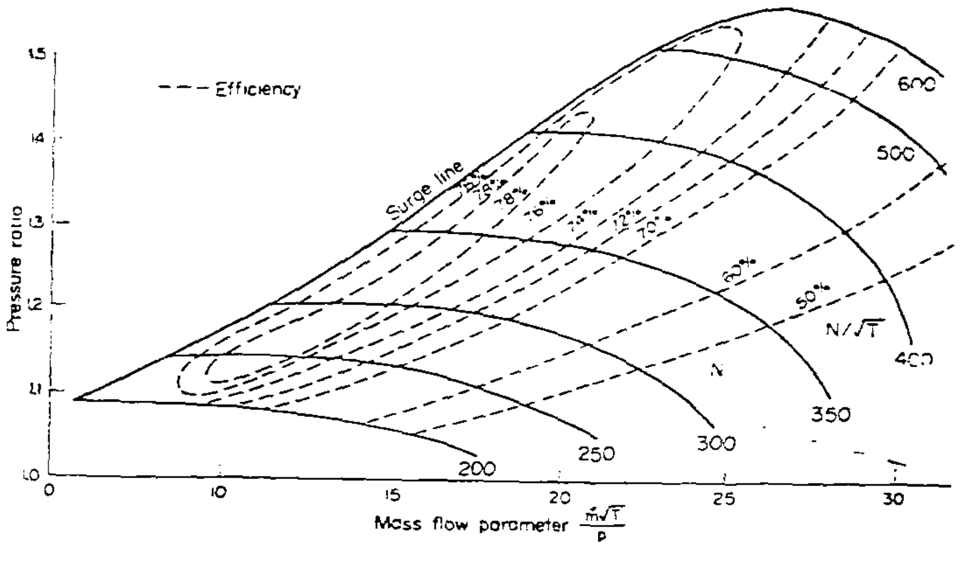

Fig 1.3 compressor characteristics $\dot{m}$, mass Flow rate; T, inlet temperature; P, inlet pressure; N, r.p.m. [2]