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المؤلف الرئيسي:	Al Mayyahi, Laith Hassan
مؤلفين آخرين:	Al Taie, Arkan K.، Ali, Emad S.(Super، Assist.super.)
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الخلاصة

النموذج يقدم مساعدة بشكل كبير لمصممي الماكينة بحيث هذا النموذج يعطي المعلومات الكاملة للماكينة للدراسة والتطوير خلال زمن وكلفة قليلين. علاوة على ذلك تعطي فهم افضل لمتغيرات الماكينة المحتواة وتأثيراتها لاداء المحرك وتعتبر أداة نافعة للحصول على افضل تصميم للمحرك لتطبيقات خاصة.

تحليل الدورة تعطي علاقات نافعة بين متغيرات الأداء مثلا نسبة الانظغاط ، نسبة الوقود إلى الهواء والوقود المستخدم.

وضع النموذج الرياضي لدراسة أداء المحرك. وهذا يحتوي على دراسة اعظم ضغط، درجة الحرارة وتوقيت القدح.النموذج الرياضي يتعامل مع محرك رباعي الشوط يعمل بالقدح غير مشحون. الطرق العددية استخدمت لحل بعض المعادلات مثل نيوتن رافسون (Newton Raphson) و رنج كوته (Runge Kutta) . برنامج حاسبي بلغة (Quick Basic) تم إعداده لإنجاز الحل.

تم دراسة أداء المحرك لظروف عمل مختلفة مثل، متوسط الضغط ، العزم ،القدرة ، معدل استهلاك الوقود والكفاءة الحرارية ووجدت افضل النتائج لهذه المتغيرات عند نسبة الوقود إلى الهواء تساوي واحد. التغير في الضغط الابتدائي ومقاومة الخليط يؤثران بشكل اكبر على الكفاءة الحرارية وأيضا على متوسط الضغط الفعال اللذان يعتمدان بصورة مباشر على كثافة الشحنة الداخلة.

تم دراسة تأثير تحليل المركبات على أداء المحرك والتي تعتبر ظاهرة مهمة للانبعاث والتلوث لدراسات لاحقة.

تم دراسة نسبة الوقود إلى الهواء على سرعة اللهب ووجدت أعلى سرعة للهبة إلى جانب الخليط الغني قليلا.

Latin symbols		
symbol	Description	unit
n	Carbon atoms in fuel	
m	Hydrogen atoms in fuel	
(F/A)	Fuel to air ratio	Kg_f/kg_a
a	Mole of fuel	Mole
N	Total mole of mixture or products	Mole
P	Pressure or power	N/m^2 or kW
V	Volume	M^3
R_{mol}	Universal gas constant	kJ/kg.mol.K
T	Temperature	K^0
n_i	NO. of moles of species i	Mole
X_i	Mole fraction of species i	/
U	Specific internal energy	kJ /kg
H	Specific enthalpy	kJ / kg
U	Total internal energy	kJ
H	Total enthalpy	kJ
Z_{ij}	Polynomial coefficient for species i	
Q_V	Heat of reaction at constant volume	kJ/kg
C_P	Specific heat at constant presure	kJ/kg.K
C_V	Specific heat at constant volume	kJ/kg.K
w	Work	kJ/kg
k	Ratio of Specific heat at constant pressure to Specific heat at constant volume	
K_P	Equilibrium constant	
CR	Compression ratio	
R_{bs}	Ratio of cylinder bore to piston stroke	
D	Bore	m
L	Stroke	m
R	Ratio of connecting rod length to crank radius	
r	Crank radius	m
ℓ	Connecting rod length	m
A	Area	M^2
rps	Rotational speed of the crank shaft	Revolution per second
g	Gibbs free energy	kJ/kg
S	Entropy	kJ/kg.K
Re	Reynolds no.	
pr	Prandtl no.	
ν	Specific volume	M^3
x	Burned mass fraction	
S.F.C	Specific fuel consumption	gr/kW.hr

AFR	Air to fuel ratio	

Creek symbols		
Φ	Equivalence ratio	
γ	Atoms of oxygen in fuel	
α	Atoms of nitrogen in fuel	
f	Residual mass fraction	
ℓ	Connecting rod length	m
θ	Crank angle	degree
r	Specific volume	M^3/kg
μ_g	Dynamic viscosity	Kg/sec.m
π	Constant	3.14
ω	Angular velocity	Rad/sec
η	Efficiency	
η_V	Volumetric efficiency	

Subscripts	
f	Fuel
a	Air
am	Ambient
i	Species or indicated
m	Mechanical
o	At absolute zero
p	Products or piston
R	Reactants
St	Stoichiometric
T	Total
j	Loop from 1 to 5
v	Constant volume
1	Initial step
2	Final step
i+1	Next STEP
d	Displacement
c	Clearance
ch	Cylinder head
u	Unburned
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Ministry of Higher Education and Scientific Research
Babylon University
College of Engineering
Department of Mechanical Engineering

Thermal Design of a Four-Stroke, Spark Ignition Engine

A Thesis

Submitted to the College of Engineering of the University of Babylon in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

By

Laith Hassan AL-Mayyahi

B.Sc. 2000

Supervisors

Dr. Arkan K. Al-Taie	Dr. Emad S. Ali

October 2002

بسم الله الرحمن الرحيم

يؤتي الحكمة من يشاء ومن يؤت

الحكمة فقد أوتي خيرا كثيرا وما

يذكر إلا أولو الألباب

صدق الله العظيم

سورة البقرة ٢٩٦

الإهداء

إلى...روح والدي الطاهرة احتراما لذكراه

إلى...ينبوع الحنان الدائم...والدتي

CERTIFICATION

We certify that this thesis entitled ***"Thermal design of a four stroke spark ignition engine "*** was prepared by ***"Laith Hassan Jawad"*** under our supervision at **Babylon University**, College of Engineering in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

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(In The Name of Allah ,The Gracious and Merciful)

*Praise be to "**ALLAH**" and his prophet **"Mohammed**". This research has been completed under their benediction.*

I would like to express my deep thanks and gratitude to my supervisors, ***Dr.Arkan K.AL-Taie & Dr.Emad S. Ali*** *for their great support, guidance, advice and assistance throughout the various stages of the present work.*

I am also indebted to the staff of Mechanical Engineering Department, and advanced computer laboratory for their facilities during my work.

I record my sincere gratitude to my family and specially to my mother for his assistance, encouragement and support during the period of preparing this work.

Finally, I would also like to thanks all my friends in Babylon University and out of it for their encouragement during the entire period of this research.

Liath Hassan Jawad
2002

ABSTRACT

Models can be of great assistance to the engine designers if they give a good representation of the engine system. Their economic value is in the reduction in time and costs for the development of new engines and their technical value is in the identification of areas which require specific attention as the design study evolves.

The cycle analysis (engine simulation) is a useful tool for the following reasons:

1.It provides a better understating of the variables involved and their effect on engine performance.

3.It is a useful tool in optimizing an engine design for a particular application.

The cycle analysis gives a useful relationship among the performance parameters, compression ratio, fuel-air ratio, and of fuel used.

The mathematical model was put to study engine performance. This included the study of the cylinder maximum temperature, pressure and spark timing. The mathematical model deals with 4-stroke, spark ignition naturally aspirated engine. Numerical methods can be used to solve some equation, such as Newton-Raphson and Runge-Kutta. A computers program in Quick Basic was constructed and developed to carry out the solution.

The engine performance studied for different operating parameters, such as mean effective pressure, torque, power, specific fuel consumption, thermal efficiency and found that optimum values for this variables at fuel-air ratio equal one.

Study the effect of dissociation of component on engine performance, and this very important to the emission and pollution for study later.

Study the effect of fuel-air ratio on flame speed , and found that the maximum flame speed for fuel-air slightly rich mixture.

Variation in initial pressure , mixture strength have only modest effect on thermal efficiency , The effects of variations in these variables on man effective pressure (mep) are more substantial , however , because mep depends directly on the initial charge density .

List of contents

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d	Displacement
c	Clearance
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CERTIFICATION

We certify that we have read this thesis, titled ***"Thermal design of a four stroke spark ignition engine"*** and as examining committee examined the student ***"Laith Hassan Jawad"*** in its contents and in what is connected with it, and that in our opinion it meets the standard of a thesis for the degree of Master of Science in Mechanical Engineering.

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CERTIFICATION

We certify that this thesis entitled ***"Thermal design of a four stroke spark ignition engine "*** was prepared by ***"Laith Hassan Jawad"*** under our supervision at **Babylon University**, College of Engineering in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

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CHAPTER 1

INTRODUCTION

1.1: General

The internal combustion engine is a heat engine that converts chemical energy into mechanical energy, which is available on a rotating output shaft. Chemical energy of the fuel is first converted to thermal energy by means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gases within the engine, and the high-pressure gas then expands against the mechanical mechanisms of the engine. This expansion is converted by the mechanical linkages of the engine to a rotating crankshaft, which is the output of the engine.the crankshaft, in turn's connected to a transmission and/or power train to transmit the mechanical energy to the desired final use There is always a need for higher power engines, and obtained the optimum engine design, therefore, the mathematical models is very signification to represent the engine and development this engine during short time.

1.2: Theory of Combustion

The combustion process in a gaseous fuel-air mixture ignited by a spark is characterized by more or less rapid development of a flame which starts from the ignition point and spreads in a continuous manner outward from the ignition point. When this flame travels or spreads continuously to the end of the chamber without any sudden change in speed or shape, the combustion is called normal. But when the mixture appears to ignite and burn ahead of the flame, the phenomenon is called autoignition which may lead to sudden increase in reaction rate and measurable pressure waves leading to what is called detonation.

In the normal combustion, there are two zone of combustion and the forward boundary of the reacting zone is called the flame front.

When a spark plug fires, the high voltage, discharge high energy ignites the air-fuel mixture between and near the electrodes. This creates a spherical flame front that propagates outward into the combustion chamber. In the initial stage, the flame front moves very slowly because of its small originated size. This is called the first stage of combustion,and the second stage is the propagation of flame front throughout the combustion chamber.

1.3:Real Engine Cycle Events

All processes of the engine cycle are illustrated in a simple as shown Fig.(1.1).

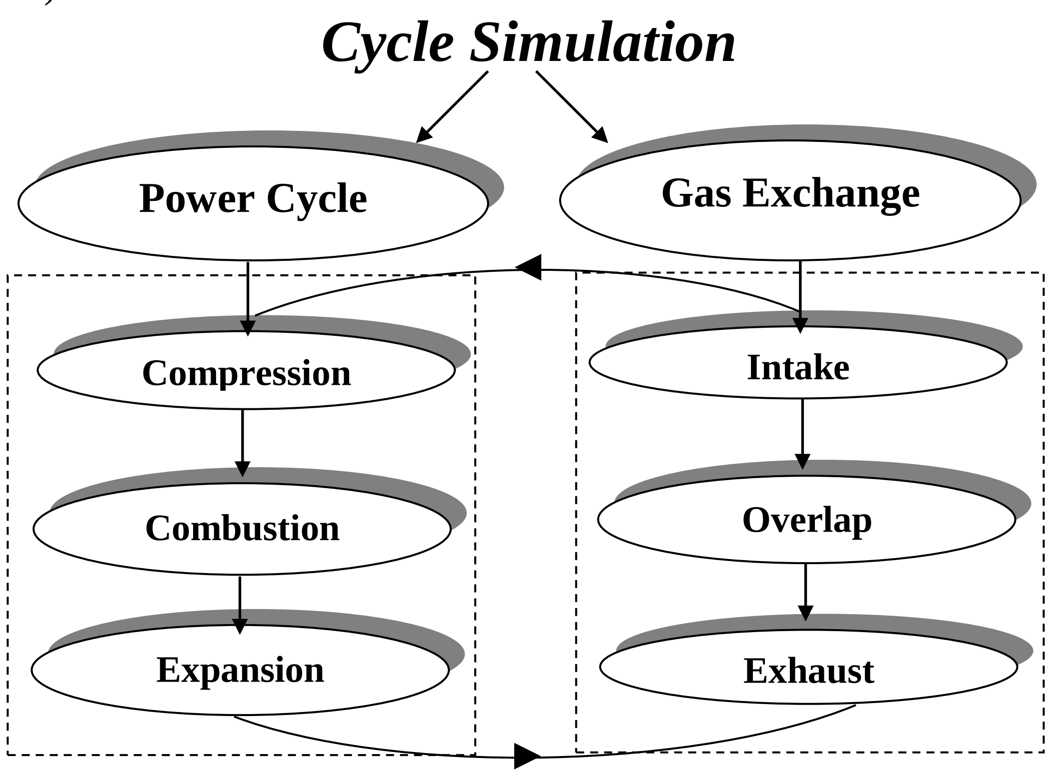

Fig.(1.1): represents the events of real cycle, 4-stroke, S.I. engine

1.4:Objective of the Present Work

The objective of this work is the modeling of a four stroke spark ignition engine. The two mathematical models can be derived and all equations programmed using (Quick Basic) language.Two computer programs is to be constructed and developed to study the engine performance. The first program is related to the ideal engine design and the second program is related to the real time engine design.

The effects of many operating parameters on engine performance are included in the mathematical models. The models will be used to predict the following parameters: engine performance such as indicated mean effective pressure, indicated thermal efficiency, brake mean effective pressure, brake thermal efficiency, indicated and brake power output, indicated and brake specific fuel consumption, temperature and pressure distribution in cylinder and torque.

All computation to be done by using step by step evaluation based on numerical method, like Newton-Raphson and Runge-Kutta methods.

The aim of the present work lies in obtaining results in a short time.for preliminary work, it might not immediately predict the optimum engine design, but it will be study the performance and obtained the optimum engine parameters which is very necessary to study and design.

1.5:Layout of the Thesis

This thesis falls into six chapters. Chapter one is an introduction and chapter two is concerned, with a brief literature review. Chapter three is devoted to the theoretical analysis that leads to the estimation of the engine performance.

Chapter four deals with the computational procedures where two computer programs are developed to perform all the calculations based on the theoretical analysis. Chapter five gives the presentation and discussion of the results. Chapter six represents the conclusions and recommendations from this work and introduces suggestions to develop this work in the future.

CHAPTER 2

LITERATURE REVIEW

2.1: Introduction

The interest in this work is directed towards S.I. naturally aspirated engine. Hence the literature survey is directed toward S.I. naturally aspirated engine, and the effect of operating parameters on performance and engine design.

2.2: Review of the Engine Study

J. Mayo [1975] studied the effect of engine design parameters on combustion rate in spark ignition engines, by calculation, shown that fast combustion rates tend to produce low NO_X levels. Their analysis has been partially confirmed by actual engine data on a highly turbulent fast burn engine. Thus , an experimental program was conducted to develop quantitative data on the effect of some of the engine design features that are known to have a significant influence on combustion rate. The effect of five engine design factors on combustion rate was determined. Burn time measured on 17 different engine configurations, each configuration containing different design levels of the five design factors. Burn time measurement was also made on a carbureted highly turbulent bowl-in piston fast burn engine with a centrally located spark plug. Significant reduction in burn time from a production combustion chamber was achieved by application of the design factors. The effect of emissions was also examined.

M.K. Gajendra Babu [1975], studied a simulation and evaluation of a four stroke single cylinder spark ignition engine, of a mathematical model. This work has two parts. The first part describes the development of the mathematical model. The instruments that were developed for the evaluation of the model are included in the second part. The simulation results are found to agree well with the experimental data. In the expansion process, the equilibrium gas composition was found. The open period, comprising the exhaust and inlet processes, was solved by computing the mass flow rate across the valves, the properties at the mesh points of the intake and exhaust systems, and the temperature and pressure of the gas in the cylinder.

At the end of cycle, resistance networks for heat transfer were set up to estimate the metal temperature. The mechanical efficiency was found by estimating friction. In the evaluation of the model, the pressure time diagram for the gases in the cylinder, in the intake system, and in the exhaust system were measured in an instrumented engine.

R, S. Benson [1975], studied a simulation model including intake and exhaust systems for a single cylinder four-stroke cycle spark ignition engine. The power cycle simulation requires only one empirical factor to correct for turbulent speed of the flame front in order to complete the cycle calculation including NO. Calculations are presented which compare well with previous work.

The model combines a full power cycle simulation with the prediction of NO emission with a comprehensive gas dynamic model for the cylinder and ducts allowing for chemical reactions in the exhaust pipe. Calculations are presented comparing the predicted NO with test results from a single cylinder engine. It is shown that good agreement is obtained between the predicted and measured NO over an equivalence range (0.8-

1.1) when the flame speed is corrected at the equivalence (0.9) corresponding to the peak NO.

S.D. Hires [1978] studied the prediction of ignition delay and combustion intervals for a homogenous charge, spark ignition engine, corrections for the ignition delay and combustion energy release intervals in a homogeneous charge, spark ignited engine are developed. After incorporation within a simplified engine cycle simulation, predicted values of these two combustion’s are based on four fundamental quantified, the turbulent integral scale, the turbulent micro scale; the turbulent intensity and the laminar flame speed.

Two empirical constants scale the correlation to a given engine. Predicted values for the ignition delay and burn intervals show good agreement with experimental results for wide variation in engine operating and design conditions (e.g.; engine speed and load, spark timing, EGR, air fuel ratio, and compression ratio) in addition, the shapes of the predicted mass fraction burned curves agree well with published data.

M. Metghalchi [1980] studied the laminar burning velocity of propane air mixtures, and has been measured in the pressure range 0.4 to 40)- atm and temperature range (298-750K) for equivalence ratios (0.8-1.5). The measurements were made in a constant volume spherical combustion bomb, which could be heated, to 500K. A thermodynamic analysis was used to calculate the laminar burning velocity from a pressure time history of the combustion process the measured values were correlated using both power law and experimental expressions.

A.C. Alkidas [1980] studied the heat transfer characteristics of a spark ignition engine, transient heat flux measurements were obtained at four position on the cylinder head of a four stroke single cylinder spark ignition engine. Tests were performed for both fired and motored operation of the engine. The primary engine operational variable was engine speed. The results showed that the heat flux varies considerably with position of measurement. At fired conditions, the initial high rate of increase of heat flux at each position of measurement correlated with calculated time arrival of the flame at that position.

Finally, as expected, the peak heat flux was found to increase with increased engine speed.

M. Metghalchi [1982], studied the burning velocities of mixtures of air with methanol, isooctane, and indolene at high pressure and temperature, have been measured using the constant volume bomb method for fuel air equivalence ratios (0.8-1.5) over the pressure and temperature ranges (0.4-50) atm and (298-700). The effect of adding simulated combustion products to stoichiometric isooctane air mixture we also studied for diluent mass fractions (0-0.2). Over the range studied, the results can be fit within $\pm 10\%$ by the functional form $S_U=S_{UO}(T_U/T_O)^{\alpha}(P/P_O)^{\varphi}(1-2.1\beta)$,where S_{UO} depends on fuel type and equivalence ratio and α and φ depend only on equivalence ratio. In overlapping ranges, the results agree well with those previously reported.

G.C. Davis [1982] studied the effect of in-cylinder flow processes (swirl, squish and turbulence intensity) on engine efficiency. The engine simulation model is a thermodynamic model coupled to sub models for the various physical processes of in cylinder swirl, squish and turbulence velocities that transfer and flame propagation.

The swirl and turbulence models are based on an integral formation of the angular momentum equation. This model account for the effects of changes in geometry of the intake system and the chamber design on in cylinder flow processes. The combustion model is an entertainment burn up model applicable to the mixing controlled region of turbulence flame propagation. The flame is assumed to propagate spherically from one or two spark plug. A heat transfer model that is dependent upon the turbulence level is used to compute the heat loss from the unburned and burned gases. These sub models are calibrated from experimental data. A parameter study is conducted to determine the effects of in cylinder geometry on burn duration, heat transfer and fuel consumption. These results indicate that swirl; squish and turbulence intensity levels can be varied to produce a minimum in fuel consumption for the conditions examined.

G.G. Lucas [1982] studied the effect of combustion chamber shape on the rate of combustion, flame propagation, the cylinder pressure for twenty on spark ignition engine combustion chamber design in spark ignition engine. These show that, for given compression ratio, the flame speed is not significantly affected by chamber design. However, the rate of combustion, the pressure history and cyclic dispersion are greatly affected. The burning velocity may be affected by combustion chamber design in two ways. First, increasing the charge to the turbulence by producing squish should also increase the burning velocity. Squish may be defined as the inward radial motion of the cylinder charge created by piston movement near TDC of the compression stroke.

F.T. Connolly and A.E.Yagle [1993] investigated a new model relating cylinder combustion pressure to crank shaft angular velocity in an interval of combustion engine, primarily the fluctuations in velocity were near the cylinder firing frequency. Experimental results that confirm a combustion pressure to angular velocity model of an IC.SI engine have been presented. This model was presented in Connolly and yagle (1992,1993) and developed and tested (via computer simulation and experimental measurements) in Connolly (1992). In particular, the model relates a random sequence parametrizing cyclic combustion pressure variability to fluctuations in angular velocity.the model takes the form of alinear, first order differential equation relating continuous combustion pressure to continuous angular velocity wave forms, as well as relating a cyclic combustion pressure variability squence to samples of angular velocity at each combustion.

Paulina. S. Kuo [1996] studied a cylinder pressure in a spark-ignition engine : a computational model. The project described in this article attempts to accurately predict the gas pressure changes within the cylinder of a spark-ignition engine using thermodynamic principles. The model takes into account the compression, combustion, and expansion that occur in the cylinder. Comparisons with actual pressure data show the model to have a high degree of accuracy. The model is further evaluated on its ability to predict the angle of spark firing and burn duration.

A.C. Alkidas [1997] studies experimentally indicators of fuel maldistribution, several exhaust emissions were found to be good indicators for fuel maldistribution (both cylinder and cylinder to cylinder) in spark ignition engines.the quality of combustion greatly affected these indicators, thus possibly limiting their applicability. Corrections were developed to desensitize these indicators to the quality of combustion.

Y.M. Yacoub [1998] studied the development and validation of a thermodynamic model for an S.I single cylinder engine, a multi zone quasi dimensional model that illustrates the intake, compression, combustion, expansion, and exhaust processes has been developed for a single cylinder four stroke spark ignition engine. The model takes into consideration mass and energy conservation in the engine cylinder, intake and exhaust plenums and crankcase plenum. The model calculates in stantaneous variations in gas thermodynamic states, gas properties, heat release rates .in cylinder turbulence, piston ring motion blow by, nitric oxide, and carbon monoxide formation. The cycle simulation accounts for induced gas velocities due to flame propagation in the turbulence model, which is applied separately to each gas one. This allows for the natural evolution of the averaged mean and turbulence velocities in burned and unburned gas regions. The present model prediction of thermal efficiency, indicated mean effective pressure, peak values of gas pressure, ignition delay, concentrations of nitric oxide, carbon monoxide and carbon dioxide are proven to be in agreement with experimental data.

Ivan. Arsie [1998] studied the models for prediction of performance and emissions in a spark ignition engine a sequentially structured approach, a thermodynamic model for the simulation of performance and emissions in a spark ignition engine is presented. The model is part of an integrated system of models with a hierarchical structure developed for the study and the optimal design of engine control strategies.

The main thermodynamic model is based on the classical two-zone approach. A multi zone model is then derived from the two zone calculation, for proper evaluation of temperature gradients in the burned gas region . The emissions of HC, CO, and NO_X are the predicted by three sub models.

The results of the thermodynamic cycle model validation, performed over more than 300 engine operating conditions, show a satisfactory level of agreement between measured and predicted data cycles.

Morea [2000] studied a multi one thermodynamic and quasi-one dimensional hybrid models applied to four-stroke spark ignition engine modeling. Model is capable to predict torque, power, specific fuel consumption, volumetric efficiency, etc; as well as instantaneous pressure, temperature, etc; within cylinder and engine manifolds. Inside the cylinder, flow is described by means of the conservation of mass principle and the first law of thermodynamics. A first order ordinary differential equation system is obtained and solved using a numerical methods. Flow in manifolds is characterized by means of the fundamental conservation equations: mass, momentum and energy. Two type mixtures are considered: fuel air mixtures and combustion products. Special attention is dedicated to real gas behavior due to specific heats are function of temperature.

Summary :-

Most of the literature published presented modeling of I.C.E. Some depend on experimental data.

The areas of interest are the study of the influence of operating parameters on engine performance.

A complete and comprehensive study is still needed to take effect of optimum operating condition on engine performance.

Ministry of Higher Education and Scientific Research
Babylon University
College of Engineering
Department of Mechanical Engineering

Thermal Design of a Four-Stroke, Spark Ignition Engine

A Thesis

Submitted to the College of Engineering of the University of Babylon in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

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تصميم محرك يعمل بالقدح رباعي الشوط من الناحية الحرارية

أطروحة

مقدمة إلى كلية الهندسة في جامعة بابل كجزء من متطلبات نيل
درجة ماجستير علوم في الهندسة الميكانيكية

قدمت من قبل

ليث حسن جواد المياحي

تشرين الأول ٢٠٠٢