PRINCIPLES AND PERFORMANCE IN DIESEL ENGINEERING

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Table of Contents

Preface

The diesel engine is recognized especially for its efficiency and reliability which explains its well established position in commercial vehicles and industrial applications. In recent years more diesels are also being used in passenger cars. Therefore diesel engineering is becoming a fast growing applied engineering discipline to meet exacting demands for designing optimum diesel engines in relation to greater efficiency and power, low noise, acceptable emissions, fuel economy and greater maintainbility.

In October 1982, Dr. Haddad organized an intensive one-week course on Diesel engineering aimed at practising engineers in the diesel and related industries. This course provided concentrated study in the various inter-related aspects of diesel engine technology: combustion and heat release; supercharging and turbocharging; test equipment; computer control and data acquisition; diesel engine design; and diesel cars and diagnostics with emphasis on automotive applications. Most of the lecturers on this course produced comprehensive lecture notes. Subsequent interest in the course content encouraged us to edit these notes into two companion books. The chapters in these books represent the accumulation of years of expertise, since each author is an expert in his field.

Diesel Engineering – Principles and Performance, covers the basic aspects of fuels, air–fuel mixing, combustion plus governing, turbocharging and exhaust emissions. *Diesel Engineering – Design and Applications,* concentrates more on mechanical design, stress, noise and vibration and application primarily to passenger cars since this is of most interest today and space precludes coverage of the variety of diesel applications.

It is important to realize that the reader is assumed to have a basic understanding of the principles of engineering thermodynamics and of internal combustion engines, though some chapters' authors have made some effort to introduce some basics as well. On the other hand, it will be found that the reader would require very little experience with I.C. engine theory but some experience with diesel engine practice in order to obtain maximum benefit from this book.

In preparing the original and revised material for this book it has been our aim to provide a useful handbook on diesel engineering, both for reference and for up to date knowledge to enable diesel engine engineers to acquire the necessary tools for further development of this most fascinating prime mover. No attempt has been made to provide a totally balanced approach to diesel engineering. Instead, the editors have tried to incorporate most detail in areas of most interest to the majority of readers.

S. D. Haddad and N. Watson

1

Combustion and heat release in diesel engines

S. D. HADDAD, Dept. of Engineering Technology, Western Michigan University

1. INTRODUCTION – IDEAL GAS CYCLES

Diesel engine combustion involves a large number of complex processes. In the past, and even at present, experience and intuition have been employed to determine the emphasis on each process. However, considerable theoretical and experimental work has been published during the last three decades, giving a better understanding of these processes and enabling most aspects of diesel engine combustion and performance to be calculated.

Before looking at diesel combustion in some detail it is appropriate to revise the basic thermodynamic principles of ideal gas cycles, in particular as to the effects of pressure, volume and temperature on thermal efficiency as follows:

(a) *Carnot cycle*

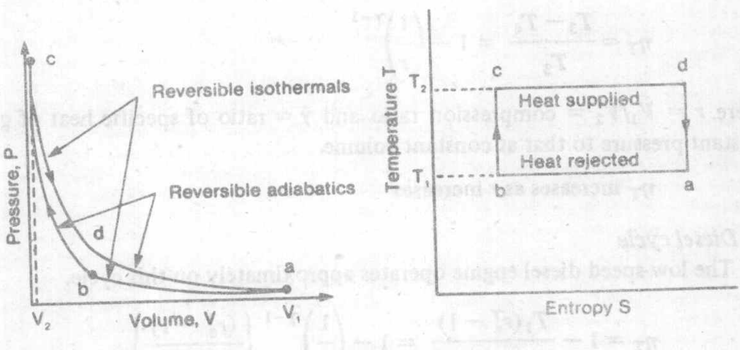

Fig. 1.

The thermal efficiency, $\eta_T = (T_2 - T_1)/T_2$.

The maximum thermal efficiency with any cycle occurs when the heat is supplied at the highest possible temperature and is rejected at the lowest possible temperature. It will be seen, therefore, that the Carnot cycle gives the highest attainable thermal efficiency for a heat engine operating between temperatures T_1 and T_2.

The cycle has two main disadvantages:

(i) *High peak pressure.* This results in increased mechanical friction and also a strengthened (and hence heavier) engine structure is needed.

(ii) *Low specific power output.* It is therefore necessary to employ a large swept volume (large engine bulk and weight) to obtain a usable amount of power.

(b) *OTTO (constant volume) cycle*

This cycle is quite closely approached in practice by the low-speed petrol engine.

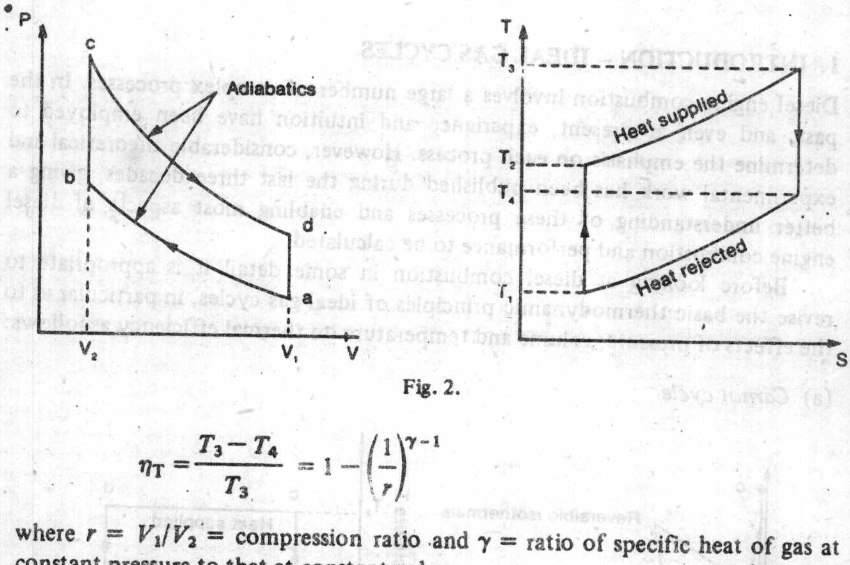

Fig. 2.

$$\eta_T = \frac{T_3 - T_4}{T_3} = 1 - \left(\frac{1}{r}\right)^{\gamma - 1}$$

where $r = V_1/V_2$ = compression ratio and γ = ratio of specific heat of gas at constant pressure to that at constant volume.

η_T increases as r increases

(c) *Diesel cycle*

The low-speed diesel engine operates approximately on this cycle.

$$\eta_T = 1 - \frac{T_1(r_e^\gamma - 1)}{T_2(r_e - 1)^\gamma} = 1 - \left(\frac{1}{r}\right)^{\gamma - 1} \left\{\frac{(r_e^\gamma - 1)}{\gamma(r_e - 1)}\right\}$$

where $r_e = V_3/V_2$.

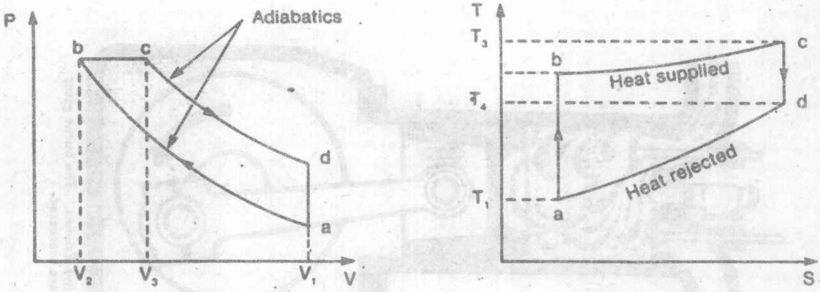

Fig. 3.

The factor $(r_e^{\gamma} - 1)/\gamma(r_e - 1)$ is usually greater than unity and increases as r_e increases. Therefore,

η_T *decreases as period of heat reception is increased*
η_T *increases as r increases*

(d) *Dual cycle*

Both high-speed petrol and diesel conform approximately to this cycle.

$$\eta_T = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \quad \frac{(p \,.\, r_e{}^{\gamma-1})}{(p-1) + p\,\gamma(r_e - 1)}$$

where, $p = P_3/P_2 = T_3/T_2$.

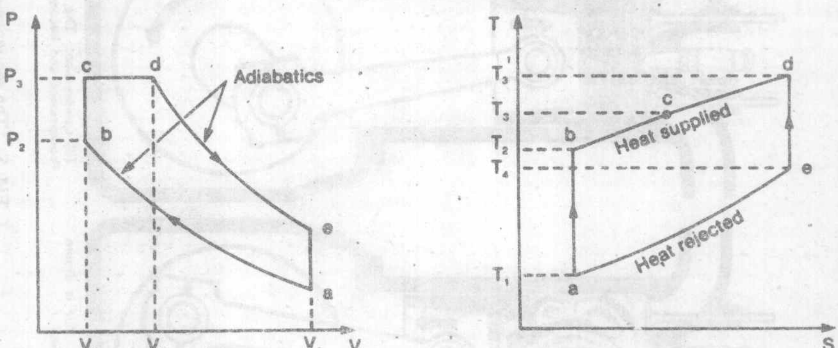

Fig. 4.

For the same compression ratio, the thermal efficiencies of the last three cycles are in the following descending order:

1. Constant volume (Otto) cycle
2. Dual cycle
3. Diesel cycle

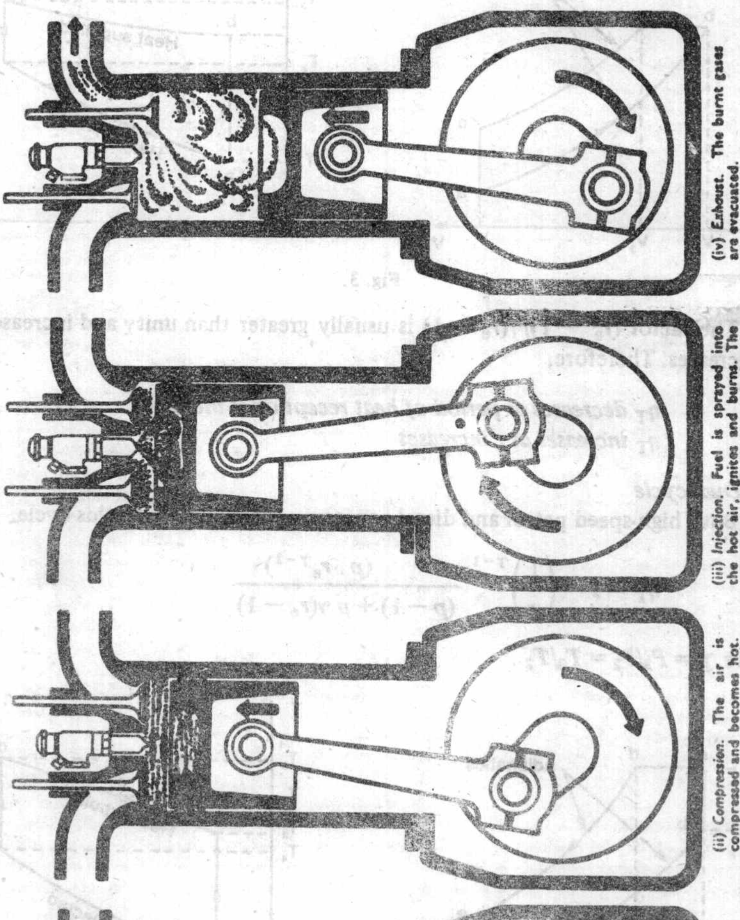

Fig. 5 – The sequence of operations in a four-stroke diesel engine.