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Motor Vehicle Fuel Economy

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Preface

Motor vehicle fuel economy is of personal interest to all engineers who drive cars, and of professional interest to the many engineers employed in the automotive industry. This book is aimed at final year students who are perhaps specialising in automotive engineering, or young graduates who are employed in the automotive industry.

Significant improvements in fuel economy have been made recently, and this is reflected in the large number of papers published in journals and conference proceedings. However, even collected papers do not provide a coherent overview of motor vehicle fuel economy, and they may pre-suppose a knowledge that is absent. Consequently, this book aims to provide a self-contained treatment of the factors that affect fuel economy, and how fuel economy is optimised.

The strategy for reducing fuel consumption has two main aspects: to provide the power required for propulsion more efficiently, and to reduce the power required for propulsion. These arguments are developed in chapter 1, and the factors that influence the fuel consumption in the real world are discussed. Spark ignition and diesel engines are discussed in chapters 2 and 3, with particular attention to the factors that govern their efficiency. Different transmission systems are discussed in chapter 4, along with powertrain matching, and optimisation for performance and fuel economy.

The factors that reduce the propulsive power requirement are discussed in chapters 5 and 6. Chapter 5 is devoted to vehicle aerodynamics, covering the topics of drag reduction, lift control and stability. The effect of drag reduction on performance and fuel economy is treated quantitatively. The rolling resistance is mostly dependent on the tyres and the vehicle mass, both of which are treated in chapter 6. Techniques for reducing the vehicle mass are particularly important in the real world, since vehicles do not travel at a constant speed on horizontal ground. Two case studies are considered in the final chapter—the Rover 800 car and the Ford Transit van. Both vehicles are analysed, to illustrate how the techniques described in the first six chapters lead to a low fuel consumption.

Throughout the book, attention is drawn to the use of micro-electronics and computing, to illustrate their contribution towards producing more fuel efficient vehicles. At the end of each chapter there are discussion points; these should enable any reader to check his or her understanding of the preceding material.

Any book owes a lot to many people. Those who deserve individual thanks are Mr J-P Pirault, Dr M L Wyszynski and Dr Neil Richardson for reading and commenting on the draft, and Ruth Sterland for the typing and inevitable retyping.

Summer 1987

RICHARD STONE

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Notation and Terminology

Notation

A	vehicle frontal area (m^2)
A_r	radiator area (m^2)
abdc	after bottom dead centre
atdc	after top dead centre
b	breadth (m)
bbdc	before bottom dead centre
bmep	brake mean effective pressure (N/m^2)
btdc	before top dead centre
C_d	drag coefficient (equation 5.1)
C_{dr}	radiator flow drag coefficient
C_l	lift coefficient (equation 5.1)
C_R	tyre rolling resistance coefficient
CAD	computer-aided design
CAE	computer-aided engineering
CAFE	corporate average fuel economy
CAM	computer-aided manufacture
CO	carbon monoxide
CTX	continuously variable transaxle
CVT	continuously variable transmission
d	characteristic dimension (m)
D	drag force (N), cylinder diameter (m)
D_d	drum diameter (m)
D_f	friction drag (N)
D_p	pressure drag (N)
D_r	radiator drag (N)
D_t	tyre diameter (m)
DI	direct injection
ECE	Economic Commission for Europe
EEC	European Economic Community

EGR	exhaust gas recirculation
EPA	Environmental Protection Agency (US)
F	force (tractive) (N)
FEM	finite element method
FMS	flexible manufacturing system
FTP	federal test procedure
g	acceleration due to gravity
gr	gearing ratio (engine speed to vehicle speed)
grp	glass fibre reinforced plastic
h	height (m)
HC	unburnt hydrocarbons
HRCC	high compression ratio compact combustion chamber
I	moment of inertia (kg m^2)
IDI	indirect injection
l	length (m)
L	stroke (m)
M	Mach number, mass (kg)
M_{eff}	effective mass (kg) (equation 5.5)
m_{f}	mass flow rate of fuel (kg/s)
MON	motor octane number
mpg	miles per gallon
mph	miles per hour
N'	engine speed, revolutions per second, divided by 2 for 4-stroke engines (equation 2.2)
NO_x	nitrogen oxides
p	tyre inflation pressure (N/m^2)
p_{b}	brake mean effective pressure (N/m^2) (equation 2.2)
ppm	parts per million (number of carbon atoms)
Q_{r}	air flow through the radiator (m^3/s)
r	radius of curvature, road wheel radius (m)
R	rolling resistance (N)
R_{td}	tyre rolling resistance measured on a drum (N)
R_{rf}	tyre rolling resistance measured on a flat surface (N)
r_{v}	volumetric compression ratio
RON	research octane number
sfc	specific fuel consumption (for example, kg/kWh)
SI	spark ignition
T	torque (N m)

TSI	timed sequential injection
v	vehicle velocity (m/s)
v_a	air velocity (m/s)
v_r	air velocity through the radiator
V_s	swept volume or displacement (m^3)
$\dot{W}$	power (kW)
$\dot{W}_b$	engine output or brake power (kW)
$\dot{W}_f$	power dissipated by friction (kW)
$\dot{W}_w$	power at the driving wheels (kW)
α	yaw angle, diesel engine load ratio
β	angle of incidence
γ	ratio of gas specific heat capacities
η	efficiency
θ	inclination of the road from the horizontal
μ	dynamic viscosity (Ns/m^2 or $kg\ m/s$)
ρ	density (kg/m^3)
τ_w	wall shear stress (N/m^2)
ϕ	equivalence ratio, local inclination of a surface
ω	angular velocity (rad/s)

Terminology

Fuel consumption is used here to mean the reciprocal of *fuel economy*. *Fuel economy* (in miles per gallon or kilometres per litre) is analogous to the efficiency of an engine. *Fuel consumption* (for example, as litres per 100 km) is the equivalent of the specific fuel consumption of an engine (kg/kWh or kg/MJ). The *road load* is the torque required of an engine that corresponds to a particular *tractive force*, *resistance* or *effort*.