The Future for Automotive Technology

Ulrich Seiffert Peter Walzer

A DEC DESERV DESERV DESERV

भाऊ भी जन्म भी

BB (

ail i

men

Henley

Research Division Volkswagenwerk Wolfsburg, West Germany

> TECHNISCHE HOCHSCHULE DARMSTADT FACHGEBIET FAHRZEUGTECHNIK PROF. DR.-ING. B. BREUER PETERSENSTRASSE 30 • 6100 DARMSTADT TELEFON 0 61 51 - 16 37 96

Frances Pinter (Publishers) London and Dover, N.H.

Contents

Lis	t of Figures	ix
For	reword	xv
Pre	face	xvii
1	Major Trends in Automotive Technology	1
2	Automobile Development and the Influence of Legislation	12
3	The Development of the Car Body and the Suspension	17
	Driving resistance	17
	Energy considerations	17
	Vehicle weight	19
	Aerodynamics	21
	Influence of air drag	21
	Development strategy for minimum drag	23
	Style and construction features	23
	Tyres	28
	Safety	28
	Accident avoidance	28
	Self-stabilizing suspensions	29
	Four-wheel drive	29
	Anti-skid systems	32
	Reduction of injuries	34
	Noise	34
	Noise sources	36
	Interior noise	37
	Exterior noise	38
	General design goals	39
	Interior space	41
	Riding comfort	41
	Production quality	44
4	The Development of Engines and Transmissions	46
	Objectives of power plant research	46
	Engine mechanics	47
	Spark-ignition engine thermodynamics	50
	 Controlling air fuel mixture and ignition 	50

Ç.

CONTENTS

e r

Problem definition	50	The Auto 2000
Present-day control systems	54	The vehicle concept
Solution of specific problems by closed loop controls	55	Aerodynamics
Knock limit control	58	Construction
Examples of a future control system	61	Interior
Combustion chamber for high compression and lean mixture Additional engine control parameters Variable compression Variable valve timing Four valves per cylinder Reduction of CO, HC and NOx emission	62 69 69 72 74	Safety features The diesel power uni The spark-ignition po Test results 8 Gas and Alcohols as Altern
Diesel engine thermodynamics Reducing soot and noise emissions Reducing soot formation	75 77 77 77 77	Perspectives Liquefied petroleum gas Fuel characteristics
Reducing noise emission	<i>81</i>	Test results of LPG ve
Direct injection	82	Engine adapted for
Supercharging	84	Engine optimized f
Consequences of future emission legislation Transmissions Manual gearbox with gearchange indicator Continuously variable transmission (CVT) Stop-start systems Stop-start system with stationary vehicle Freewheeling Semi-automatic stop-start system Stop-start system with freewheel clutch Employment of flywheel inertia 5 Electronics in the Automobile	92 93 93 95 98 98 98 98 99 99 99 100 102	Alcohol fuels Properties of alcohol : Pure alcohol fuels Alcohol-petrol fue Spark-ignition engines Methanol engines Methanol/ethanol Alcohol fuels in diese Fuel blends Dual-fuel operation Pure methanol
Trends towards electronics	102	9 Alternative Types of Engine
Special requirements	103	Selection of promising d
Electronics concept and microcomputer systems	105	High-temperature gas tur
6 Alternative Materials for the Car Body and the Engine	109	Electric drive
Reasons for the use of alternative materials	109	Electro-hybrid
Aluminium	111	10 Traffic and Transportation
Plastics	112	Solutions for city traffic
Ceramic materials	118	Traffic flow between towns
7 Integrated Research Vehicles The IRVW I The IRVW II	124 124 124	Alternative means of transp

vii

	The Auto 2000	132
	The vehicle concept	132
	Aerodynamics	133
	Construction	135
	Interior	138
	Safety features	140 141
	The diesel power unit	143
	The spark-ignition power unit Test results	146
	Test results	110
8	Gas and Alcohols as Alternative Fuels	147
	Perspectives	147
	Liquefied petroleum gas (LPG)	147
	Fuel characteristics	147
	Test results of LPG vehicle	149
	Engine adapted for LPG and petrol	149
	Engine optimized for LPG operation	150
	Alcohol fuels	150
	Properties of alcohol fuels	150
	Pure alcohol fuels	150
	Alcohol-petrol fuel blends	154
	Spark-ignition engines with alcohol-petrol fuel blends	157
	Spark-ignition engines adapted for pure alcohol fuels	158
	Methanol engines	159
	Methanol/ethanol engines	159 161
	Alcohol fuels in diesel engines	161
	Fuel blends	161
	Dual-fuel operation Pure methanol	162
9	Alternative Types of Engines	163
	Selection of promising drive units	163
	High-temperature gas turbine	165
	Electric drive	167
	Electro-hybrid	170
0	Traffic and Transportation Systems	174
	Solutions for city traffic	174
	Traffic flow between towns	175
	Alternative means of transport	178
	-	



1

CONTENTS

viii

à

11	Some Influential Factors: Energy, Ecology, Economics	
	and Politics	182
	Future fuel supplies	182
	Research into effects of exhaust gas	183
	Economic and political trends	185
	4 ⁷	
Bił	bliography	188
Inc	lex	193

List of figures

Figure	1.1	Yearly world demand
Figure	1.2	Passenger cars per 1,
Figure	1.3	Contribution of diffe
		traffic in the Federal
Figure	1.4	Improvement of mai
		Audi passenger cars c
Figure	1.5	Development of the :
		over the years
Figure	1.6	Number of legislative
Б,	1 -	over the years
Figure	1.7	Future demands on a
Figure	1.8	Measures to improve
W :-	1 0	future demands on th
Figure	1.9	Measures to improve
Figure	1 10	influence on future d
Figure	1.10	Measures to improve
Figure	1 1 1	on future demands or Measures to impress
Figure	1.11	Measures to improve
		transmission managen
Figure	1.12	future demands on th Possible sources of en
Figure	1.12	Advantages of alterna
1 igute		and light trucks
Figure	1.14	Measures to improve
	T	on future demands or
Figure	2.1	European safety regul
Figure	2.2	European emissions le
Figure	2.3	Evolution of Europea
Figure	2.4	US corporate average
-		US domestic car fleet
Figure	3.1	Legal fuel economy te
Figure	3.2	Distribution of propu
•		in the ECE test cycle
Figure	3.3	Finite element plan fo
Figure	3.4	Engine-compartment
		plastic and steel mate
Figure	3.5	Definition of aerodyn
Figure	3.6	Drag coefficient c _D o
Figure	3.7	Stages of development

List of figures

÷

×.			
Firme	1.1	Yearly world demand for passenger cars	1
02	1.2	Passenger cars per 1,000 inhabitants	2
Figure		Contribution of different means of transportation to the	2
Figure	1.3	traffic in the Federal Republic of Germany	2
, 12:	1 4	Improvement of main transportation criteria of Volkswagen-	2
Figure	1.4	Audi passenger cars over the years	3
F imme	15		3
Figure	1.5	Development of the average income and the cost of a car	3
Elemente	1 4	over the years Number of legislative regulations for automobiles	3
Figure	1.6	over the years	4
Figure	1.7	Future demands on automobile development	5
Figure	1.8	Measures to improve the car body and their influence on	5
Figure	1.0	future demands on the automobile	6
Figure	1.9	Measures to improve the spark-ignition engine and their	0
riguie	1.7	influence on future demands on the automobile	7
Figure	1.10	Measures to improve the diesel engine and their influence	'
Figure	1.10	on future demands on the automobile	8
Figure	1.11	Measures to improve the transmission and the engine-	0
riguie	1.11	transmission management and their influence on the	
		future demands on the automobile	8
Figure	1.12	Possible sources of energy for cars in the year 2000	9
Figure	1.12	Advantages of alternative power plants for passenger cars	
Tiguit	1.15	and light trucks	10
Figure	1.14	Measures to improve the traffic flow and their influence	10
I Iguit	1.1.1	on future demands on the automobile	11
Figure	2.1	European safety regulations	13
Figure	2.2	European emissions legislation	14
Figure	2.3	Evolution of European noise legislation	15
Figure	2.4	US corporate average fuel economy standards (CAFE).	
0		US domestic car fleet and VW-Audi fleet	16
Figure	3.1	Legal fuel economy test procedures	18
Figure	3.2	Distribution of propulsion energy and fuel consumption	
U		in the ECE test cycle	19
Figure	3.3	Finite element plan for a car body	20
Figure	3.4	Engine-compartment hood in sandwich construction from	
÷		plastic and steel materials	21
Figure	3.5	Definition of aerodynamic drag coefficient c _D	22
Figure		Drag coefficient c _D of 252 passenger cars, status 1983	22
Figure	3.7	Stages of development for a low drag car	24
-			

o All Sind

FIGURES

Figure	3.8	Influence of style and construction features on air drag	25	Figure	4 1 3	
Figure		Influence of cooling system position on air drag and	La J	Figure		
	2.,	cooling air speed	27	Figure		
Figure	3.10	Measures to reduce rolling resistance of tyres and		Figure		
	0120	influence on other driving characteristics	28	1 Aguit		
Figure	3.11	Front axle design and negative king-pin offset,		Figure	4.17	
B	••••	Volkswagen Golf, 1984	30	Figure		
Figure	3.12	Rear axle design and toe-correcting bearings,	• •	1 iguie	1.10	
	•••=	Volkswagen Golf, 1984	31	Figure	4 1 9	
Figure	3.13	Four-wheel drive layout, Audi Quattro	32	Figure		
		Correlation between the coefficient of friction and	• -	Figure		
	••••	the slip of the tyres	33	Figure		
Figure	3.15	Comparison of different anti-skid devices for front-		Figure		
	••••	wheel drive cars. Anti-skid system superimposed to		Figure		
		standard diagonal braking system	35	1 iguit	1.21	
Figure	3.16	Exterior forces on the structure of the car body and		Figure	4 25	
B	••••	deformation of the side member in a crash—		Figure		
		comparison between simulation and actual test results	36	I iguite	7,20	
Figure	3.17		37	Figure	4 27	
Figure			38	Figure		
Figure			39	Figure		
Figure			40	i iguit	1.27	
Figure			42	Figure	4 30	
Figure				i iguite	1.50	
1 .5	0.22	of wheel EFR on optimum K-value	43	Figure	4 31	
Figure	3.23	Air spring suspension system	43	Figure		
		Pre-assembling of body components	45	Figure		
Figure		Mechanical efficiency map, 1.3 ltr spark-ignition	15	Figure		
I iguite		engine	47	Figure		
Figure	42	Distribution of frictional losses	48	Figure		
Figure		Fuel consumption as function of starting	70	Figure		
Tigure	1.5	temperature and operation time	49	Figure		
Figure	4 4	Operating ranges of an engine	51	Figure		
Figure		Knock limit as function of ignition timing and air/	J 1	Tigure	т.,,	
riguit	т.у	fuel ratio	51	Figure	4 40	
Figure	46	Specific fuel consumption and specific NOx-emission	<i>J</i> 1	Figure		
Figure	т.0	as function of air/fuel ratio and ignition timing	52	riguie	T. T1	
Figure	47	Influence of a variation in air/fuel ratio on the	52	Figure	4 17	
Figure	т./	variation of mean effective pressure	53	Figure	7.72	
Figure	48	Functional and cost comparison of carburettor	55	Figure	1 12	
Inguie	1.0	and fuel injection system	54	Figure		
Figure	49	Ignition advance mapping of a mechanical and an	JT	Figure		
Inguie	1.2	electronical system	56	Figure	5.1	
Figure	4 10		50	Figure	5 2	
i iguic	1.10	output parameters	57	Figure		
Figure	4 1 1	Hologram of engine block at knocking	59	Figure	0.1	
Figure			60	Figure	6 1	
5		Letter Burton System with Knock control	00	Figure	0.2	

Adaptive kno Engine govern Electronic cor Combustion c engine

Test results at

Test results at

Diesel particule

Particulate filte

Combustion pr idling with diff

Combustion ch

and direct injec Engine maps of

Superchargers a

The Comprex p

WOT-torque ac

Specific fuel co

Transient behav Relative advant

Possible future Engine map wit methods

Components of Schematic of a drive mechanism Performance an CVT transmissic Start-stop with Start-stop syster Trend towards u automobile Electronic centr Breakdown of c

vehicles

Distribution of r

chambers Simulation of Alternative co Thermal effici Test results wi Valve stroke a Test results of slide valve Four valves per Spark-ignition emission contr

х

1

₽ נ

7

ł

e

S

1

(

2

1

1

1

٤

1

i

1

		FIGURES	xi
Figure	4.13	Adaptive knock control	61
Figure		Engine governor with partial control loops	62
Figure		Electronic control system for spark-ignition engine	63
Figure		Combustion chamber comparison—spark-ignition	
8		engine	64
Figure	4.17	Test results at WOT with different combustion chambers	66
Figure		Test results at part-load with different combustion	
0 .		chambers and	67
Figure	4.19	Simulation of combustion processes	68
Figure		Alternative control methods for spark-ignition engines	70
Figure	4.21	Thermal efficiency with variable compression ratio	70
Figure	4.22	Test results with variable compression ratio	71
Figure		Valve stroke and charge speed at WOT-load, 1.3 ltr engine	73
Figure		Test results of variable valve timing using a rotary	
U		slide valve	74
Figure	4.25	Four valves per cylinder	76
Figure		Spark-ignition engine without and with full exhaust	
-		emission control	78
Figure	4.27	Diesel particulate filter	80
Figure	4.28	Particulate filter regeneration	81
Figure	4.29	Combustion pressure traces and noise emission at	
		idling with different temperatures	82
Figure	4.30	Combustion chamber comparison—swirl type	
		and direct injection diesel engine	83
Figure	4.31	Engine maps of swirl chamber and direct injection diesel	84
Figure	4.32	Superchargers and their installation	86
Figure	4.33	The Comprex pressure-wave process	87
Figure	4.34	WOT-torque achieved with different supercharging methods	88
Figure	4.35	Specific fuel consumption of supercharged engines	89
Figure	4.36	Transient behaviour of different supercharging methods	89
Figure	4.37	Relative advantages of the different supercharging methods	91
Figure	4.38	Possible future exhaust-gas emission legislation	92
Figure	4.39	Engine map with operational lines of different transmission	
		methods	94
Figure		Components of the shift and fuel consumption indicator	95
Figure	4.41	Schematic of a continuously variable transmission with chain	
		drive mechanism	96
Figure	4.42	Performance and fuel consumption of a standard and a	
		CVT transmission—simulation results	97
Figure		Start-stop with clutch freewheel	100
Figure		Start-stop system with flywheel inertia usage	101
Figure	5.1	Trend towards using electronic components in the	
	. -	automobile	102
Figure	5.2	Electronic centres in the car	107
Figure	6.1	Breakdown of cost factors in the production of motor	
		vehicles	110
Figure	6.2	Distribution of materials for alternative car concepts	110

t

3

1

ł

1

ł

ŀ

in the set

dr At

É,

Sh

Ŀe,

ey eral

18Y

y and

S

igure	6.3	Plastics used in contemporaneous automobiles,					Test results o
		Volkswagen Golf	112		-		WOT charact
igure	6.4	Specific strength and modulus of elasticity of various			Figure	8.14	
		high-strength fibre compositions	113				load of diffe
Figure	6.5	Body and interior components made from reinforced			Figure		Energy chair
,		plastics	114		Figure		100 kW auto
Figure	6.6	Axles from sheet metal and from glass-fibre-reinforced			Figure		Ceramic con
527		plastic	116		Figure	9.4	Volkswagen
Figure		Connecting rod from carbon fibre plastic	117				systems
Figure		Properties of ceramic materials	118		Figure		Specification
Figure		Turbocharger turbine rotor from SiC material	120		Figure		Drive unit s
Figure		Diesel engine components from ceramic materials	121		Figure	9.7	Energy prop
Figure		Effects of diesel engine combustion chamber insulation	122				electro-hybr
Figure		Integrated research Volkswagen No. 1, IRVW I	125		Figure 1		Traffic rout
Figure		Technical data of the IRVW I	126		Figure 1	0.2	On-board gu
Figure		Injury protection of the IRVW I	127				motorist, A
Figure		Crash test results of the IRVW I	128		Figure 1	L0.3	Display of g
Figure		Turbocharged diesel engine of the IRVW I	129		Figure 1		Impression
Figure		Fuel economy and pollutant emissions of the IRVW I	130		Figure 1	l0.5	Preference t
Figure		Integrated research Volkswagen No. II, IRVW II	131		Figure 1	1.1	Developmer
Figure		Technical data of the IRVW II	132		Figure 1	1.2	Structure of
Figure		Crash test results of the IRVW II	132		-		world crude
		Fuel consumption data of the IRVW II	133		Figure 2	1.3	Exhaust-gas
		Volkswagen research car Auto 2000	134		Figure 1		Expenditure
		Auto 2000 in wind tunnel testing	136		5		Volkswagen
		Auto 2000 constructural concept	137		Figure 3	11.5	Leading aut
•		Auto 2000 interior	139	• • *	5		-
Figure	7.15	Auto 2000-1.2 ltr, 3-cyl. DI-diesel engine with		•			
		turbocharger	142	i			
Figure	7.16	Auto 2000—1.06 ltr, 4-cyl. spark-ignition engine with					
		variable transmission driven Roots-charger	144				
Figure	7.17	Operational data of the VW-Auto 2000	145				
Figure		Properties of petrol and LPG	148				
Figure	8.2	Future LPG supply from various countries	149				
Figure	8.3	Estimates for LPG-vehicles in various countries in 1990	150				
Figure		Scheme of fuel system of alternative operation on					
•		petrol and LPG	151				
Figure	8.5	Main data of LPG concept vehicle	151				
Figure		Test results of engine for alternating use of petrol or LPG,					
-		compared to standard petrol engine	152				
Figure	8.7	Test results of engine optimized for LPG use, compared					
~		to standard petrol engine	152				
Figure	8.8	Properties of alcohol fuels	152				
Figure		Vapour pressure of different fuels	153				
		Change in distillation by admixture of methanol and					
+)oure_							
gure		ethanol	155				

•••••

xii

-

T A U

> ן 1 פ

	FIGURES	xiii
Figure 8.12	Test results of fifteen M15 vehicles	158
Figure 8.13	WOT characteristics of a 4-cyl. pure methanol engine	160
Figure 8.14	Specific energy consumption as a function of road	
-	load of different engines	161
Figure 9.1	Energy chain of coal, from primary energy to the road	164
Figure 9.2	100 kW automotive gas turbine	165
Figure 9.3	Ceramic components for high temperature gas turbine	168
Figure 9.4	Volkswagen research cars with electric power plant	
ξ.	systems	169
Figure 9.5	Specification of electro-hybrid passenger car	171
Figure 9.6	Drive unit system of electro-hybrid passenger car	172
Figure 9.7	Energy proportions of fuel and electric current in	
	electro-hybrid use	173
Figure 10.1	Traffic routing and navigation display	176
Figure 10.2	On-board guidance and information system for	,
	motorist, ALI	177
Figure 10.3	Display of guidance system in the Auto 2000	179
Figure 10.4	Impression of future guided motorway traffic	180
Figure 10.5	Preference to different transportation systems	181
Figure 11.1	Development of crude oil supply	182
Figure 11.2	Structure of world crude oil consumption and of	
	world crude oil production	183
Figure 11.3	Exhaust-gas sequences from source to effects	184
Figure 11.4	Expenditure for research and development in the	
	Volkswagen Group	186
Figure 11.5	Leading automobile manufacturers in 1978	187

£

lls

y 2000

y rel

W