## Contents

| Pref         | ace   | vii |  |
|--------------|---|-----|--|
| Abo          | out the authors   | ix  |  |
| Introduction |   |     |  |
| Part         | 1 Electromotive Technology (Ron Hodkinson MSc MIEE)                             | 1   |  |
| 1            | Current EV design approaches  | 3   |  |
|              | 1.1 Introduction  | 3   |  |
|              | 1.2 Case for electric vehicles  | 3   |  |
|              | 1.3 Selecting EV motor type for particular vehicle application                  | 15  |  |
|              | 1.4 Inverter technology   | 21  |  |
|              | 1.5 Electric vehicle drives: optimum solutions for motors, drives and batteries | 24  |  |
| 2            | Viable energy storage systems   | 29  |  |
|              | 2.1 Electronic battery  | 29  |  |
|              | 2.2 Battery performance: existing systems                                       | 29  |  |
|              | 2.3 Status of the aluminium battery   | 35  |  |
|              | 2.4 Advanced fuel-cell control systems  | 39  |  |
|              | 2.5 Waste heat recovery, key element in supercar efficiency                     | 50  |  |
| 3            | Electric motor and drive-controller design                                      | 56  |  |
|              | 3.1 Introduction  | 56  |  |
|              | 3.2 Electric truck motor considerations   | 56  |  |
|              | 3.3 Brushless DC motor design for a small car                                   | 58  |  |
|              | 3.4 Brushless motor design for a medium car                                     | 61  |  |
|              | 3.5 Brushless PM motor: design and FE analysis of a 150 kW machine              | 64  |  |
|              | 3.6 High frequency motor characteristics  | 68  |  |
|              | 3.7 Innovative drive scheme for DC series motors                                | 73  |  |
| 4            | Process engineering and control of fuel cells,                                  |     |  |
|              | prospects for EV packages   | 80  |  |
|              | 4.1 Introduction  | 80  |  |
|              | 4.2 Reforming and other hydrogen feedstocks                                     | 82  |  |
|              | 4.3 Characteristics, advantages and status of fuel cells                        | 83  |  |
|              | 4.4 Thermodynamics of fuel cells  | 84  |  |

## vi Contents

|      | 4.5        | Process engineering of fuel cells  | 87         |
|------|------------|--|------------|
|      | 4.6        | Steps towards the fuel-cell engine   | 89         |
|      | 4.7        | Prospects for EV package design  | 93         |
|      | 4.8        | Fuel-cell vehicles and infrastructure  | 96         |
|      | 4.9        | The PNGV programme: impetus for change   | 98         |
| Part |            | / Design Packages/Design for Light Weight                                      | 103        |
|      | (J         | ohn Fenton MSc MIMechE)  |            |
| 5    | Batt       | ery/fuel-cell EV design packages   | 105        |
|      | 5.1        | Introduction   | 105        |
|      | 5.2        | Electric batteries   | 105        |
|      | 5.3        | Battery car conversion technology  | 115        |
|      | 5.4        | EV development history   | 119        |
|      | 5.5        | Contemporary electric car technology   | 122        |
|      | 5.6<br>5.7 | Electric van and truck design Fuel-cell powered vehicles                       | 128<br>135 |
|      | 3.7        | ruei-cen powered venicies  | 133        |
| 6    | Hyb        | rid vehicle design   | 141        |
|      | 6.1        | Introduction   | 141        |
|      | 6.2        | Hybrid drive prospects   | 143        |
|      | 6.3        | Hybrid technology case studies   | 146        |
|      | 6.4<br>6.5 | Production hybrid-drive cars Hybrid passenger and goods vehicles               | 156<br>164 |
|      | 0.3        | Hybrid passenger and goods venicles  | 104        |
| 7    | Ligh       | tweight construction materials and techniques                                  | 173        |
|      | 7.1        | Introduction   | 173        |
|      | 7.2        | The 'composite' approach   | 173        |
|      | 7.3        | Plastic mouldings for open canopy shells                                       | 178        |
|      | 7.4        | Materials for specialist EV structures   | 182        |
|      | 7.5<br>7.6 | Ultra-lightweight construction case study Weight reduction in metal structures | 191<br>192 |
|      |            |  | 192        |
| 8    |            | ign for optimum body-structural and running-gear ormance efficiency            | 199        |
|      | -          | •  |            |
|      | 8.1<br>8.2 | Introduction Structural package and elements                                   | 199<br>200 |
|      | 8.3        | 'Punt'-type structures   | 209        |
|      | 8.4        | Optimizing substructures and individual elements                               | 211        |
|      | 8.5        | Designing against fatigue  | 217        |
|      | 8.6        | Finite-element analysis (FEA)  | 218        |
|      | 8.7        | Case study of FEA for EVs and structural analysis assemblies                   | 223        |
|      | 8.8        | Running gear design for optimum performance and lightweight                    | 223        |
|      | 8.9        | Lightweight vehicle suspension   | 231        |
|      | 8.10       | Handling and steering  | 232        |
|      | 8.11       | Traction and braking systems   | 235        |
|      | 8.12       | Lightweight shafting, CV jointing and road wheels                              | 241        |
|      | 8.13       | Rolling resistance   | 243        |
| Inde | Index      |  |            |