Passenger Cars

Overall Trends

1 Introduction

The automotive industry in 2013 showed signs of economic recovery in developed markets and strong demand in key markets. In contrast, the previous strong growth of China and other emerging nations slowed somewhat. It was also a year in which environmental regulations in these countries were strengthened.

The number of passenger cars sold in the 49 main countries of the world during the full year in 2013 was 59.12 million vehicles. This was an increase of 4.3% compared to the previous year and continued the increasing trend since 2012. In comparison, sales of passenger cars in Japan reached 4.56 million vehicles, a slight decrease of 0.2% from the previous year. Although sales in Japan remained near the same level as 2012, the number of vehicles produced in Japan fell to 8.19 million units, 95.7% of the previous year, due to a decrease in the number of exports.

Since 2011, fuel prices around the world have remained persistently high and every automaker has been promoting technological innovations to improve fuel economy and environmental performance. The Japanese market in 2013 also showed that the movement toward more environmentally friendly and fuel-efficient vehicles, such as mini-vehicles, hybrid vehicles (HEVs), and plug-in HEVs (PHEVs) is accelerating.

2 State of Vehicle Production, Sales, and Exports

2. 1. State of production in leading manufacturing countries

2. 1. 1. State of production according to country

The number of passenger cars produced worldwide in 2013 was 65.43 million vehicles, an increase of 3.7% compared to the previous year (Table 1).

Many automakers increased production due to the economic recovery in the U.S. and the subsequent recovery in demand. China accounts for approximately 30% of the world's total vehicle production. New vehicle purchases, replacement demand, and last-minute demand spurred by concerns over total production volume controls contributed to a huge increase in production of 16.5% compared to the previous year in China.

In contrast, passenger car production decreased in India due to a stagnant economy, in South Korea due to sluggish domestic production and exports, and in Japan, where demand is still depressed due to the lingering effects of the end of the preferential tax scheme for envi-

Table 1 Passenger car production in leading manufacturing countries.

	2013	2012	2013/2012 (%)
Japan	8 189 323	※ 8 554 503	95.7
U.S.	4 346 958	※ 4 105 874	105.9
Canada	965 191	1 040 298	92.8
Germany	5 439 904	※ 5 388 459	101.0
UK	1 509 762	1 464 906	103.1
France	1 460 000	1 682 814	86.8
Italy	388 465	396 817	97.9
Spain	1 719 700	1 539 680	111.7
EU	14 613 286	※ 14 631 710	99.9
South Korea	4 122 604	4 167 089	98.9
China	18 085 213	15 523 658	116.5
India	3 138 988	※ 3 296 240	95.2
Brazil	2 742 309	※ 2 589 236	105.9
World total	65 433 287	※ 63 070 002	103.7

※ Revised

Note 1) The values announced by the International Organization of Motor Vehicle Manufacturers (OICA) are preliminary figures. There are 27 countries in the EU.

Note 2) The number of vehicles for the U.S. and Canada excludes SUVs and other models that are considered as trucks in those countries.

Table 2 Passenger car production according to manufacturer and country.

Ranking in 2013	Ranking in 2012	Manufacturer	Country	2013	2012	2013/2012 (%)
1	2	Hyundai group	South Korea	3 091 731	3 125 607	98.9
2	1	Toyota	Japan	3 021 519	3 170 289	95.3
3	3	VW group	Germany	2 185 979	2 158 444	101.3
4	4	BMW	Germany	1 112 727	1 043 732	106.6
5	8	Mercedes-Benz	Germany	1 006 340	963 633	104.4
6	11	Mazda	Japan	950 834	830 294	114.5
7	5	Nissan	Japan	854 057	1 035 726	82.5
8	10	GM	U.S.	831 854	840 700	98.9
9	7	Honda	Japan	805 499	996 832	80.8
10	9	Suzuki	Japan	797 385	886 781	89.9
11	12	GM Daewoo	South Korea	757 719	768 449	98.6
12	14	American Honda	U.S.	733 998	639 108	114.8
13	16	Fuji Heavy Industries	Japan	639 756	※ 550 176	116.3
14	13	Ford Germany	Germany	608 710	685 358	88.8
15	17	Toyota	U.S.	607 623	531 876	114.2
16	15	Daihatsu	Japan	602 210	633 887	95.0
17	20	Ford	U.S.	553 446	419 907	131.8
18	19	Mitsubishi	Japan	518 063	※ 450 518	115.0
19	18	Nissan	UK	501 756	※ 510 572	98.3
20	21	Nissan	U.S.	470 232	※ 406 782	115.6
21	22	Fiat Group	Italy	386 346	394 620	97.9
22	24	GM Canada	Canada	297 853	※ 319 556	93.2
—	6	PSA	France	—	1 017 436	
—	23	Renault	France	—	359 532	

Source: Automobile manufacturers association in each country
Note 1) Value for Daimler/Chrysler
Note 2) There is no SEAT (VW) numerical data for 2011
※ Revised

ronmentally friendly vehicles in 2012.

The EU has emerged from the effects of the European debt crisis and signs of economic recovery are beginning to appear. Vehicle production for the entire EU rallied to 99.9% compared to the previous year due to increases in the leading EU nations of vehicles destined for export outside the EU.

2. 1. 2. Production according to manufacturer

Although Toyota was ranked in first place last year and the production of the Toyota group (including Daihatsu, Hino, commercial vehicles, and production outside Japan) as a whole exceeded 10 million vehicles for the first time of any group in the world, the number of passenger cars produced in Japan by Toyota decreased. As a result, the Hyundai group seized first place in this category. Three German automakers, the VW Group, BMW, and the Daimler Group, increased production and took the other places in the top 5.

The other Japanese automakers increased local production in the main market of North America and reduced production in Japan. However, Mazda and Fuji Heavy Industries still have high Japanese production ratios. The rankings of these companies were boosted by increased production for export (Table 2).

Table 3 Passenger car sales in Japan.

	2013	2012	2013/2012 (%)
Standard vehicles	1 399 407	1 411 700	99.1
Small vehicles	1 472 704	1 602 951	91.9
4-wheeled mini-vehicles	1 690 171	1 557 681	108.5
Total	4 562 282	4 572 332	99.8

Source: Japan Automobile Manufacturers Association (JAMA)
Note 1) The classification criteria of the sales statistics are based on the license plate number.

2. 2. State of Japanese vehicle sales, exports, and production

2. 2. 1. Sales

The number of passenger cars sold in Japan in 2013 was 4.56 million vehicles, almost unchanged from 2012 (99.8%) (Table 3). Although the market for small vehicles is shrinking in Japan, booming demand for mini-vehicles is offsetting the reduction in sales of small and standard vehicles.

There was some underlying negative demand in the first half of the year due to the lingering effects of the end of the incentive system for environmentally friendly vehicles. However, in the second half of the year Japanese automakers introduced new and refreshed models that had a positive effect on sales. In addition, there was another significant surge in sales during the fourth quarter due to last-minute demand before the consumption tax increase in April 2014. As a result, there was a nice recovery late in the year that made up for the early loss in sales (Table 9).

2. 2. 2. Exports

The number of Japanese passenger cars exported in 2013 was 4.07 million vehicles, a decrease of 3.1% compared to the previous year (Table 4).

Exports to regions such as the Middle-East, South America, and Africa increased, but the number of vehicles destined for Europe, which is second only to North America, declined significantly by 17% compared to the previous year. The number of vehicles exported to Oceania and Asia also decreased.

North America accounts for approximately 45% of all Japanese passenger car exports and this is the largest destination market. The number of vehicles exported to North America remained the same as the previous year because Japanese manufacturers are promoting the transfer of production capabilities to the local markets in that region.

Table 4 Number of passenger cars exported from Japan according to destination.

	2013	2012	2013/2012 (%)
North America	1 862 967	1 863 688	100.0
Europe	691 849	833 397	83.0
Oceania	361 004	394 762	91.4
Asia	355 563	※ 378 890	93.8
Middle-East	432 263	386 729	111.8
Central America	122 328	121 712	100.5
South America	170 350	151 029	112.8
Africa	67 428	66 537	101.3
Other	1 801	1 750	102.9
Total	4 065 553	4 198 494	96.8

Source: JAMA
※ Revised

2. 2. 3. Production

The number of passenger cars produced in Japan in 2013 decreased for the first time in 2 years to 8.19 million vehicles, 4.3% lower than the previous year (Table 5). Each Japanese automaker is expanding production outside Japan and the decrease in the number of vehicles for export also had an effect on production.

However, production of mini-vehicles did increase. As a result, the number of mini-vehicles produced in 2013 was close to the production of small vehicles.

Table 5 Passenger car production in Japan.

	2013	2012	2013/2012 (%)
Standard vehicles	4 618 014	4 686 396	98.5
Small vehicles	1 888 759	2 252 672	83.8
4-wheeled mini-vehicles	1 682 550	1 615 435	104.2
Total	8 189 323	8 554 503	95.7

Source: JAMA

2. 2. 4. Used vehicle sales

The number of used vehicles sold in 2013 increased slightly to 5.66 million vehicles, 107.2% of the level in the previous year (Table 6).

The number of trade-in mini-vehicles is increasing in

Table 6 Used vehicle sales in Japan.

	Standard vehicles	Small vehicles	4-wheeled mini-vehicles	Total	Compared to previous year (%)
1996	1 233 553	3 750 582	836 474	5 820 609	104.6%
1997	1 406 089	3 626 978	1 009 430	6 042 497	103.8%
1998	1 493 744	3 309 426	1 111 282	5 914 452	97.9%
1999	1 551 703	3 127 783	1 273 383	5 952 869	100.6%
2000	1 742 786	3 050 087	1 448 546	6 241 419	104.8%
2001	1 830 588	2 913 775	1 552 297	6 296 660	100.9%
2002	1 861 694	2 744 604	1 714 827	6 321 125	100.4%
2003	1 910 017	2 640 456	1 809 840	6 360 313	100.6%
2004	1 984 562	2 524 764	1 777 866	6 287 192	98.9%
2005	2 002 563	2 460 410	1 890 154	6 353 127	101.0%
2006	1 959 739	2 304 226	2 033 569	6 297 534	99.1%
2007	1 810 596	2 105 122	2 022 866	5 938 584	94.3%
2008	1 728 090	1 944 766	1 995 333	5 668 189	95.4%
2009	1 619 370	1 855 071	1 864 874	5 339 315	94.2%
2010	1 592 110	1 816 696	1 873 466	5 282 272	93.2%
2011	1 542 614	1 733 519	1 906 523	5 182 656	91.4%
2012	1 688 606	1 826 335	2 133 725	5 648 666	105.8%
2013	1 666 732	1 740 725	2 255 560	5 663 017	107.2%

Sources: Japan Automobile Dealers Association (JADA) and the Japan Light Motor Vehicle and Motorcycle Association

Table 7 Imported vehicle sales in Japan.

Ranking in 2013	Ranking in 2012	Manufacturer	2013	2012	2013/2012 (%)
1	1	VW	67 279	56 188	119.7
2	3	Mercedes-Benz	53 720	41 901	128.2
3	4	BMW	46 037	41 102	112.0
4	2	Nissan (vehicles produced outside Japan)	35 680	42 410	84.1
5	5	Audi	28 676	24 163	118.7
6	6	BMW MINI	16 982	16 212	104.7
7	7	Volvo	16 918	13 878	121.9
8	8	Mitsubishi (vehicles produced outside Japan)	12 429	12 764	97.4
9	9	Fiat	7 007	5 667	123.6
10	10	Peugeot	5 970	5 649	105.7
11	11	Jeep	4 928	4 977	99.0
12	12	Porsche	4 869	4 661	104.5
13	16	Ford	3 896	3 543	110.0
14	17	Renault	3 771	3 108	121.3
15	18	Land Rover	3 347	1 771	189.0
16	14	Alfa Romeo	3 148	4 452	70.7
17	13	Toyota (vehicles produced outside Japan)	3 014	4 660	64.7
18	15	Citroen	2 947	3 795	77.7
19	—	Chrysler	1 774	777	228.3
20	19	smart	1 298	1 401	92.6
	—	Other	7 596	7 515	101.1
			331 286	300 594	110.2

Source: JAMA
※ Revised

Table 8 Passenger car sales in leading manufacturing countries and share of Japanese vehicles.

	2013	Japanese vehicles (within the total)	Share of Japanese vehicles (%)	2012	2013/2012 (%)
Japan	4 562 282	4 283 436	93.9	4 572 332	99.8
U.S.	7 585 867	3 134 889	41.3	※ 7 243 654	104.7
Canada	754 952	315 886	41.8	748 530	100.9
Brazil	2 763 718	316 127	11.4	2 851 540	96.9
China	17 928 858	3 066 385	17.1	15 495 240	115.7
India	2 583 224	1 349 007	52.2	※ 2 780 772	92.9
UK	2 264 737	347 306	15.3	2 044 609	110.8
Germany	2 952 431	254 996	8.6	3 082 504	95.8
France	1 790 456	172 654	9.6	1 898 760	94.3
Italy	1 304 345	131 407	10.1	※ 1 403 008	93.0
EU + EFTA total	12 312 046	1 525 566	12.4	※ 12 523 650	98.3

Source: Automobile manufacturers association in each country
Note 1) Japanese vehicles refer to all Japanese brand vehicles and include those produced outside Japan.
Note 2) The number of vehicles for the U.S. and Canada excludes SUVs and other models that are considered as trucks in those countries (Source: Ward's).
Note 3) Calculated from the 27 countries in the EU and 3 countries in the European Free Trade Association (EFTA: Iceland, Norway, and Switzerland) (source: European Automobile Manufacturers' Association (ACEA)).
※ Revised

conjunction with the growing sales of new mini-vehicles. The number of used mini-vehicle sales is therefore also growing. Sales of both new and used small vehicles are continuing to fall. Since 1995, the number of small vehicle sales has dropped by more than one-half in 20 years.

2. 2. 5. Imported vehicle sales

A closer look at the sales of passenger cars in Japan shows a noticeable increase in imported vehicle sales (Tables 7 and 8).

The number of imported vehicles sold in Japan in 2013 was 330,000 units, 110.2% of the level in the previous year, and continues the trend of significant year-on-year growth. The share of imported vehicles in the Japanese market also rose from 5.2% in 2012 to 6.1% in 2013.

The sales of almost all non-Japanese automakers in 2013 exceeded those of the previous year. Particularly

Table 9 Global regional passenger car sales by quarter compared to previous year (%).

			2013 total	1st quarter	2nd quarter	3rd quarter	4th quarter
49 countries around the world			4.3	2.4	2.1	4.8	8
3 countries in North America			4.5	2.8	4.9	7.5	2.8
4 countries in South America			0.1	2.8	8.3	−7.4	−1.6
18 countries in Western Europe			−1.9	−9.8	−3.5	2.2	5.6
8 countries in Central & Eastern Europe			−1.6	0.4	−5.5	−2.6	1.7
12 countries in Asia			8.7	8.3	4.2	8.6	13.6
	Japan		−0.2	−9.2	−7.5	1.7	20.3
		Mini-vehicles	8.5	2.9	−3.4	12.9	26.5
		Registered vehicles	−4.7	−14.9	−10	−4	17.1
	China		15.7	17.2	10.4	14.5	20.3
	India		−7.9	−10.8	−7.7	−4.2	−7.9
Oceania			2.4	1.8	4	3.7	0.1
	Australia		2	1.8	3.7	3	−0.7
	New Zealand		7.3	1.8	7.2	10.7	9.6
2 countries in Africa			−0.3	3.8	10.9	−6.6	−7.1

Source: FOURIN

popular were small vehicles from European manufacturers with good fuel efficiency and a lower price point of 3 million yen per vehicle or less. The demand for foreign luxury cars was also strong due to the economic recovery and this also helped to drive the increase in sales of imported vehicles.

2. 3. Vehicle sales in markets outside Japan

The number of passenger cars that were sold in the 49 leading countries of the world during 2013 increased by 4.3% overall compared to the previous year (Table 9).

China and the U.S. are the number 1 and number 2 markets respectively for passenger car sales and those markets both showed strong increases in sales in 2013. However, the effects of the economic downturn in Western European countries and a deceleration in emerging markets were both very noticeable during the first half of the year.

Particularly in the case of India, the pullback in consumer spending has continued due to high fuel costs and high interest rates, leading to a significant decrease in vehicle sales.

Sales of imported vehicles from European manufacturers have grown strongly in Japan and China. At the same time the market shares of Japanese brand vehicles, decreased slightly, including of vehicles produced outside Japan.

3 Product Technology Trends

3. 1. Trends according to classification (standard vehicle/small vehicle/mini-vehicle)

In 2013 11 new standard and small vehicle models and 9 new mini-vehicle models were launched in Japan, including original equipment manufacturing (OEM) models (excluding some derivative models).

Of the 11 new standard and small vehicle models, 8 were HEVs, including one from Fuji Heavy Industries, which means that every Japanese automaker has now decided to promote technological development as the most important area for improving vehicle environmental performance and fuel efficiency technologies (Tables 12 and 13).

3. 2. Fuel efficient and environmentally friendly technologies

In 2013, the situations in oil producing nations and the depreciation of the yen led to a continuing trend of rising fuel prices. Since 2008, this was the first time in 4 years that the retail price of gasoline exceeded 160 yen per liter. Therefore, improving the fuel efficiency of conventional gasoline-powered vehicles has become a serious and pressing issue.

Some of the main technologies used in 2013 to improve fuel efficiency were engines with direct fuel injection (DI) and variable valve timing (VVT) to improve combustion efficiency, improved engine parts to reduce friction, and improved CVT systems. The new models launched in 2013 all featured these kinds of improved engines and

Table 10 Main fuel efficiency-related technologies adopted on passenger cars in 2013.

Name of technology	Model and manufacturer	Details
Sport Hybrid i-MMD	Accord Hybrid from Honda	Equipped with two motors for driving and power generation
ECO Cruise Control	XV Hybrid from Fuji Heavy Industries	Technology that links EyeSight system and hybrid system drive. The vehicle is equipped with an automatic traffic following function in EV mode to match the pace of the vehicle ahead detected by the EyeSight system. EV mode can be maintained up to a speed of 80 km/h. Careful control of the air conditioning and other factors allows this technology to improve actual fuel efficiency by approximately 10%.
SPORTS HYBRID i-DCD	Fit Hybrid from Honda	A 7-speed dual clutch transmission (DCT) with a built-in electric motor and parallel hybrid system using an Atkinson cycle engine to improve both dynamic performance and fuel efficiency.
K24W 2.4-liter DOHC i-VTEC engine and newly developed CVT	Odyssey from Honda	A 2 .4-liter DI DOHC i-VTEC inline 4-cylinder engine was developed. The engine was completely revamped from the frame up and the next-generation of the environmentally friendly Earth Dreams Technology was incorporated. Maximum output of 129 kW/6,200 rpm and maximum torque of 225 Nm/4,000 rpm. The Odyssey Absolute Grade has improved output due to its DI engine. This was combined with a CVT that features a 19% larger gear ratio coverage.
P5-VPS DI engine SKYACTIV-G1.5	Axela from Mazda	Water-cooled inline 4-cylinder DOHC 16-valve engine. Displacement of 1,496 cc and compression ratios of 13.0 and 14.0. Maximum output of 82 kW/6,000 rpm and maximum torque of 144 Nm/3,500 rpm. Torque was increased significantly and fuel efficiency was improved by approximately 26% (compared to previous model).
XTronic CVT (new model)	X-Trail from Nissan	The gear range was expanded and friction resistance loss was reduced. A new step-shift control mechanism that raises the engine speed to match increases in vehicle speed was adopted.
New generation 3B20 MIVEC DOHC 12-valve engine	eK Wagon from Mitsubishi Motors (Dayz from Nissan)	Water-cooled inline 3-cylinder DOHC 12-valve MIVEC (refined version of the 3B20 model). Displacement of 659 cc and a compression ratio of 12.0. Maximum output of 36 kW/6,500 rpm and maximum torque of 56 Nm/5,500 rpm (coasting stop function is available with naturally aspirated (NA) idling stop specifications). An electronic controlled thermostat and water-cooled external exhaust gas recirculation (EGR) cooler were adopted. Other improvements include changes to the cooling paths and reduced valve train friction.

powertrains. In addition, idling stop mechanisms were added to some vehicles as standard equipment and the use of regenerative braking mechanisms was also expanded (Table 10).

Reducing vehicle weight is directly linked to improved fuel efficiency and ultra-high strength (1,000 MPa-class or higher) steel has been adopted even in certain areas of mini-vehicles as the use of lightweight materials is expanding. Carbon fiber reinforced plastic (CFRP) is also attracting attention as a lightweight material for vehicles. Although this material has not yet been put into full-scale use in body structures, research and development aimed at further reducing its cost is being actively promoted.

In addition to these technologies, controls for hybrid systems are also being improved. One HEV launched in 2013 attained a maximum fuel economy of 37.0 km/L. Many other non-HEVs in 2103 also achieved the 2015 fuel efficiency standard +20% and the 2015 fuel efficiency standard +10% threshold for tax exemptions (the full amount and 75% tax exemption respectively).

The environmental performance of vehicles was also addressed in 2013. In addition to technologies to improve fuel efficiency, the purification performance and durability of catalysts were also improved in 2013, while also reducing the precious metal content. As a result, many vehicles introduced in 2013 were certified as attaining the 2005 emissions standard 75% reduction threshold level for tax exemptions.

3. 3. Safety technologies

In addition to the technologies that improve fuel efficiency, advanced safety vehicle (ASV) technologies have also been increasingly adopted in recent years.

Starting in October 2012, all new and updated models

Table 11 Current state and characteristics of collision mitigation braking technologies.

Sensor type	Characteristics	Manufacturer & name of technology	Speed at which stopping is possible	Operation speed
Laser and radar	Objects are detected by infrared laser. Inexpensive. Detection range is short and is affected by direct sunlight.	Daihatsu Smart Assist	4～20 km/h	Approximately 30 km/h or slower
		Suzuki Radar Brake Support	5～15 km/h	Approximately 5 to 30 km/h
		Honda City-Brake Active System	～30 km/h	Approximately 30 km/h or slower
		Mazda SCBS	4～15 km/h	Approximately 4 to 30 km/h
Cameras (stereo/monocular)	Can detect pedestrians and vehicles. Affected by the weather.	Subaru EyeSight	～30 km/h	All vehicle speeds
		Toyota PCS (for pedestrians, avoidance support type)	～40 km/h	At all vehicle speeds of approximately 5 km/h or higher
		Nissan Emergency Brake	～30 km/h	Approximately 10 to 80 km/h
Millimeter-wave radar	Objects are detected by millimeter-wave radar. Long-range detection is possible.	Toyota PCS (damage mitigation type)	Stopping not supported	At all vehicle speeds of approximately 15 km/h or higher
		Toyota PCS (avoidance support type)	～30 km/h	At all vehicle speeds of approximately 15 km/h or higher
		Toyota PCS (for pedestrians, avoidance support type)	～40 km/h	At all vehicle speeds of approximately 5 km/h or higher
		Honda CMBS	～30 km/h	All vehicle speeds
		Nissan Emergency Brake	～60 km/h	All vehicle speeds
		Mazda SBS	15～30 km/h	Approximately 15 km/h to high speed range
		Mitsubishi Motors e-Assist	～30 km/h	All vehicle speeds

Table 12 Standard and small vehicles introduced in 2013 by leading Japanese manufacturers and technological trends.

Release date	Model	Manufacturer	Major details
April 8	Mebius	Daihatsu	New model (OEM of Toyota's Prius Alpha) Equipped with a 1.8-liter hybrid system that achieves fuel economy of 26.2 km/L in the JC08 test cycle.
May 16	IS	Toyota (Lexus)	Full model change (added models). IS300 : First hybrid specifications for IS. Equipped with inline 4-cylinder 2.5-liter engine almost identical to the one in the Crown Hybrid. Achieved 23.3 km/L in JC08 test cycle and CO_2 emissions of 100 g/km. New IS350 : New rear suspension and an 8-speed sports direct shift (SPDS) were adopted. F Sport: Movable dashboard meters were adopted. IS350 F sport: The Lexus Dynamic Handling System (LDH) was adopted. The platform is modified from the 4th generation GS. New manufacturing methods such as laser screw welding (LSW) and structural adhesives were adopted to reduce the pitch between spot welding points. Improved body stiffness and lighter weight realized by expanding the use of high-strength steel sheets. Pop-up hood and lane departure alert (LDA) adopted for the first time on a Lexus model.
June 21	Accord Hybrid, Accord Plug-in Hybrid	Honda	New model Equipped with a hybrid system called SPORT HYBRID i-MMD. Equipped with an LFA 2.0-liter inline 4-cylinder DOHC 16-valve i-VTEC engine and an electric CVT with a built-in integrated clutch and 2 coaxial motors. Equipped with an electric servo brake system. Coordinated operation of hill-start assist, adaptive cruise control (exclusive equipment for the Accord Hybrid EX), and an advanced crash mitigation braking system (CMBS) that considers both the vehicle ahead and oncoming vehicles (exclusive equipment for the Accord Hybrid EX) was achieved. Realizes 30.0 km/L (in JC08 test cycle) by automatic switching between 3 driving modes: EV, hybrid, and engine. Accord Plug-in Hybrid: Utilizes the characteristics of the SPORT HYBRID i-MMD and is equipped with a newly developed PHEV system with a large capacity lithium battery. An EV mode range of 37.6 km was achieved. A combined fuel economy rating of 70.4 km/L (in JC08 test cycle) was achieved.
June 24	XV Hybrid	Fuji Heavy Industries	New model Subaru's own unique AWD hybrid system was adopted. Equipped with a 2.0-liter horizontally-opposed 4-cylinder DOHC engine designed exclusively for HEVs by reducing friction. A dedicated transmission with integrated drive motor for HEVs was developed based on the Lineartronic CVT. Full-time AWD with a simple structure was adopted that allows transmission of torque to all four wheels via the AWD when the engine is powering the vehicle, in hybrid mode, and in EV mode at low speeds when the engine is disconnected. Heavy parts, such as the high-voltage battery, are concentrated underneath the trunk space to help ensure the same front/rear and left-right weight distribution and center of gravity height as the base vehicle (XV). All grades achieved the 2015 fuel efficiency standard +20% threshold. Vehicles equipped with the EyeSight (Ver. 2) system include the newly developed ECO cruise control system as an exclusive function for HEVs. EV mode is utilized when the cruise control with traffic following function that operates at all speeds is activated to help improve actual fuel efficiency.

Table 12 Standard and small vehicles introduced in 2013 by leading Japanese manufacturers and technological trends (cont.).

Release date	Model	Manufacturer	Major details
August 6	Corolla Axio, Corolla Fielder Hybrid	Toyota	New model HEVs (models: NKE165 /165 G) were added. Equipped with the 1.5-liter THS-II with reduction gear mechanism hybrid system. Fuel economy of 33.0 km/L in JC08 test cycle. Achieved the 2015 fuel efficiency standard +20% threshold. Certified as achieving the 2005 emissions standard 75% reduction level. An Atkinson cycle engine was adopted. Equipped with a cooled EGR system. A switch to select either eco-drive mode or EV mode was made standard equipment. A vehicle approach warning device was made standard equipment. Hill-start assist control was made standard equipment. HID view assist package now available. A 4.2-inch TFT multi-information display and analog dual gauge meter with tachometer were adopted.
September 6	Fit, Fit Hybrid	Honda	Full model change Equipped for the first time with the 1-motor-type hybrid system called the SPORT HYBRID Intelligent Dual Clutch Drive (i-DCD). An inline 4-cylinder 1.5-liter Atkinson cycle engine with excellent fuel efficiency was adopted. Uses a combination of a 7-speed DCT with built-in high-output motor and an intelligent power unit (IPU) with built-in lithium-ion battery. The adoption of an electric servo brake system and full electric compressors improved the fuel efficiency by 35% or more (compared to the previous IMA hybrid system). Fuel economy of 36.4 km/L was realized, the highest in Japan. The engine and motor connect and disconnect according to the running state, so the vehicle has 3 different drive modes: EV mode where only the motor provides power, hybrid mode where both the engine and motor provide power, and engine mode where only the engine provides power. Equipped for the first time with the City-Brake Active System that helps mitigate collisions and injuries via automatic brakes that use laser radar to sense other vehicles ahead (operates when the vehicle speed is between 5 and 30 km/h).
November 1	Odyssey, Odyssey Absolute	Honda	New model A newly developed K24W engine was adopted. A direct fuel injection system was added to the variable valve timing and lift mechanism (VTEC) and continuously variable valve timing and control mechanism (VTC). A 2.4-liter DI DOHC i-VTEC engine was adopted (Odyssey Absolute). A port injection-type 2.4-liter DOHC i-VTEC engine was adopted (B, G, and G/EX). A new CVT was developed. High efficiency and reduced weight were achieved by improving the transmission efficiency and consolidating functions. This led to improvements in both acceleration performance and fuel efficiency. Drive-by-wire (DBW) that responds quickly to accelerator operation and coordinated control of the CVT called G-design Shift were adopted. Equipped with 7-speed mode and paddle shifters (Odyssey Absolute). An ultra-low floor platform was constructed. Premium grade seats were adopted for the second row. The chassis was newly designed to increase stiffness for all parts, starting with the suspension. Body stiffness was also increased, particularly around the joints. The turning angle of the tires was increased and a minimum turning radius of 5.4 meters was realized. Equipped with a multi-view camera system. Equipped with driving support functions, such as the Honda Smart Parking Assist System. Safety equipment such as blind-spot information, an unintended acceleration control function, advanced CMBS with millimeter-wave radar, and the City-Brake Active System were adopted. The 2015 fuel efficiency standard +20% was achieved (front-wheel drive (FWD) and 7-occupant seating specifications).
November 21	Axela	Mazda	Full-model change A design theme called Soul of Motion was adopted. The front wheels were positioned 50 mm further forward to expand the legroom of the driver's seat. The interference between the wheel house and the accelerator pedal was eliminated and an optimized pedal position was realized. The A pillar was moved backward 100 mm from its position on the previous model to help ensure driving visibility. Seats with a new structure were adopted to expand the contact area around the waist. A newly developed gasoline engine called the SKYACTIV-G 1.5 with significantly better torque and approximately 26% higher fuel efficiency was adopted (sedan two-wheel drive (2WD) automatic transmission (AT) vehicle, JC08 test cycle comparison). A 4-2-1 exhaust was newly adopted on the SKYACTIV-G 2.0. Compared to the same engine with the 4-1 exhaust used on the previous model, torque increased and fuel economy improved by approximately 9% (sporty 2WD AT vehicle, JC08 test cycle comparison). The SKYACTIV-D 2.2 produces torque equivalent to a 4.0-liter V8 gasoline engine, while conforming to the post new long-term emissions standards without using an expensive NOx aftertreatment device. The SKYACTIV-HYBRID was developed as a new dedicated HEV engine based on the SKYACTIV-G 2.0, achieving a fuel economy of 30.8 km/L in the JC08 test cycle. The SKYACTIV-DRIVE (6-speed AT) locks up the clutch in almost all speed regions except for during acceleration from a stop and makes smooth and quick gear changes possible, while the SKYACTIV-MT (6-speed manual transmission (MT)) allows the driver to shift gears with just the flick of a wrist. An electric CVT was adopted for the HEV. The car connectivity system called Mazda Connect was adopted in the interior equipment. Vehicles equipped with the SKYACTIV-G 1.5 (2WD) and SKYACTIV-G 2.0 (AT) qualify for the 75% tax reduction under the preferential tax scheme for environmentally friendly vehicles, while vehicles equipped with the SKYACTIV-HYBRID engine qualify for a tax exemption. Newly developed active air shutters were adopted on vehicles equipped with the SKYACTIV-G 2.0. These shutters block the flow of air through the opening in the lower grille when there is no need to cool the engine. This improves the aerodynamic performance of the vehicle, contributes to a shorter warm-up time, and improves actual fuel efficiency. An idling stop system and deceleration energy recovery system called i-ELOOP are now standard equipment (on vehicles with SKYACTIV-G 2.0 and SKYACTIV-D 2.2 engines). Lightweight and highly stiff bodies were adopted. Collision mitigation-type body structures were also adopted. The Mazda Radar Cruise Control (MRCC), High Beam Control (HBC) system, SRS airbag system (driver and front passenger seats, curtain, and front side), Hill Launch Assist (HLA), and Emergency Signal System are now all standard equipment. The vehicle Distance Recognition Support System (DRSS), Forward Obstruction Warning (FOW), Lane Departure Warning System (LDWS), Adaptive Front lighting System (AFS), and Rear Vehicle Monitoring (RVM) system were also adopted. The vehicles are also equipped with Smart Brake Support (SBS), Smart City Brake Support (SCBS), and AT involuntary acceleration suppression and control.

Table 12 Standard and small vehicles introduced in 2013 by leading Japanese manufacturers and technological trends (cont.).

Release date	Model	Manufacturer	Major details
December 2	Harrier	Toyota	Full-model change A panoramic view monitor (with left and right verification support) is now available. A steering control function was added to the LDA system. A pre-crash safety system (millimeter-wave radar type) and intelligent clearance sonar are also now available. Drive start control is standard equipment on all vehicles. HEV: Fuel economy of 21.8 km/L (CO_2 emissions: 106 g/km) in the JC08 test cycle realized by combining the 2.5-liter 2AR-FXE engine and the hybrid system. 2.0-liter gasoline engine vehicle: Adopting Valvematic technology and a CVT realized smooth and powerful acceleration. The idling stop function was adopted, achieving a fuel economy of 16.0 km/L (CO_2 emissions: 145 g/km) (2WD vehicle) in the JC08 test cycle. HEV and 2.0-liter gasoline engine (2WD) vehicle: Achieved the 2015 fuel efficiency standard +20% threshold. All vehicles certified as achieving the 2005 emissions standard 75% reduction level and qualify for tax reductions under the preferential tax scheme for environmentally friendly vehicles.
December 16	X-Trail	Nissan	Full-model change Converted to a crossover SUV. Equipped with ALL MODE 4×4-i system with world's first chassis control (active ride control and active engine brake) technologies. All vehicles have cornering stability assist as standard equipment. An emergency braking package grade of the vehicle is available that that activates emergency braking when objects are detected by the front camera, mistaken pedal operation collision prevention assist, lane departure warning (LDW), and no-entry sign detection. A blind spot warning (BSW) system that uses the rear camera and vehicle swerving alert functions are available as options. Vehicles are equipped with intelligent parking assist and advanced drive assist displays. A good fuel economy of 16.4 km/L was realized by equipping the vehicles with a DI MR20DD engine, idling stop function, and the new Xtronic CVT. All vehicle grades achieved the 2015 fuel efficiency standard +10% threshold and 2005 emissions standard 75% reduction level, qualifying for a 75% reduction in tax. Waterproof luggage boards in the trunk and seats with spinal support functions were also adopted. The vehicles are also equipped with a power tailgate with a hands-free opening function.
December 20	Vezel	Honda	New model Developed under a concept called Expansible Cockpit, the interior design achieves both spaciousness and a personal feel. The Automatic Brake Hold function is standard equipment on every type of this vehicle. Outstanding quietness was realized through the adoption of high-performance sound absorbing and insulating materials. Amplitude reactive dampers were adopted. An inner-frame structure and ultra-high strength sheet steels were used for approximately 20% of the overall body frame to help realize a lightweight and highly-stiff body. A pedestrian injury mitigation body was adopted. A side curtain airbag system and a front seat i-side airbag system (variable capacity type) are available as a set in some types of this vehicle as part of the Peace-of-mind Package. Hybrid vehicle: The Reactive Force Pedal system is available as standard equipment on all types of this vehicle. The SPORT HYBRID i-DCD uses 1.5-liter DI engine technology. The hybrid model achieves 27.0 km/L (in JC08 test cycle), the highest fuel economy for an SUV in Japan. This is the first time that Honda had equipped a HEV with its four-wheel drive (4WD) system called Real Time AWD. Gasoline engine vehicle: Gasoline engine models are equipped with a 1.5-liter DI engine that achieves excellent fuel economy of 20.6 km/L (in JC08 test cycle).

Source: PR materials published by each passenger car manufacturer

must be equipped with electronic stability control (ESC). Consequently, all models launched in 2013 have ESC, tire slip-prevention functions, and traction control systems as standard equipment (existing models must also add such equipment after October 2014).

The collision mitigation braking technology that has been adopted on standard and small vehicles is now also being expanded to mini-vehicles as well. Some mini-vehicles have adopted a simple and comparatively inexpensive infrared laser system to detect the vehicle ahead, while the adoption of millimeter-wave radar and camera systems have been promoted for standard and small vehicles. Luxury models are equipped with even higher definition vehicle detection technologies with added functions by combining multiple detection and safety systems. Furthermore, systems launched in 2013 featured automatic vehicle stopping functions, which were not part of the first generation of collision mitigation braking systems, and an expanded range of operation speeds (Table 11).

More and more vehicles are designed with bodies that help to reduce injuries to pedestrians. Luxury models are now often equipped with pop-up hoods and lane departure warning functions that use camera sensors to help protect pedestrians. In 2013 the Volvo V40 became the first vehicle in the world to be equipped with an airbag for pedestrians.

In addition to these safety technologies and devices, a growing number of models are now equipped with a variety of different safety sensor and detection functions, such as emergency stop signals (as standard equipment) to alert following vehicles of sudden braking, vehicle ap-

Table 13 Mini-vehicles introduced in 2013 by leading Japanese manufacturers and technological trends.

Release date	Model	Manufacturer	Major details
March 15	Spacia	Suzuki	New model A new platform was adopted for this vehicle with a 2,425 mm-long wheel base. An interior length of 2,215 mm was realized. The vehicle weight was reduced by 90 kg. A new lightweight impact-absorbing body (TECT), a front bumper that protects the occupant's legs, and neck-impact mitigating front seats were adopted. High-strength steel sheets were used for approximately 42% (weight ratio) of the entire body. High-strength steel sheets up to the 1,180 MPa-class were used to help achieve a lightweight and highly stiff body. The R06A engine was improved. The timing chain was made narrower, reducing weight and friction (wear resistance). The vehicle is equipped with a newly developed radiator that is approximately 30% slimmer than the previous model. The heat dissipation efficiency was improved by reforming the fins, and heat dissipation performance almost equivalent to the previous model was achieved. The tank for the cooling water and other parts were also reduced in size. The CVT was improved. The engine control and CVT control were optimized by using the VVT engine and this made it possible for the vehicle to run in more efficient engine speed ranges. The CVT differential case was reduced in weight. The front hubs were integrated into a single structure with the front axle bearings, and the structure of the rear axle bearings was reviewed so that the rolling resistance could be reduced. Lightweight brake calipers and brake discs were adopted. Vehicle comfort was ensured through improving ride comfort and reducing noise. Tires with reduced rolling resistance were adopted. A front bumper and windshield molding with shapes with excellent aerodynamic characteristics were adopted. Pendulum-type engine mounts were adopted (on the 2WD vehicle) to reduce interior noise and body vibrations. A sound absorbing-type of molded roof was adopted for the interior. A fuel economy of 29.0 km/L was achieved due to Suzuki Green Technologies such as eNe-CHARGE, a new idling stop system, and eco-cool. The turbocharged and 2WD versions of this vehicle also achieved a good fuel economy of 26.0 km/L (in JC08 test cycle). The turbocharged, 2WD, and 4WD versions of the vehicle all qualified for the eco-car tax exemption. A front stabilizer is equipped to help ensure good ride comfort while also controlling roll when cornering (X, T). A hill-hold control that inhibits the vehicle from rolling backwards on a hill is now standard equipment on all models. A security alarm system and immobilizer (approved by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)) are also standard equipment.
April 25	Flair Wagon	Mazda	Full-model change The interior and exterior designs were changed. The base vehicle was changed to the Spacia. The eNe-CHARGE, idling stop system, and eco-cool were all adopted. The VVT engine and a CVT with auxiliary gearbox mechanism were adopted. The vehicle weight was reduced by 90 kg. The 2005 emissions standard 75 % reduction level (4 stars) was achieved. All of the vehicles qualified for the eco-car tax exemption due to achieving the 2015 fuel efficiency standard +20% threshold. A navigation system that can connect to smart phones is also available on all vehicles as a manufacturer's option.
June 6	Dayz	Nissan	New model A fuel economy of 29.2 km/L (in JC08 test cycle) was realized by adopting a 3-cylinder engine, CVT with auxiliary transmission, and a lightweight body. This vehicle qualifies for exemptions from the vehicle purchase and eight taxes. The Around View Monitor and a touch panel-type automatic air conditioner were adopted for the first time on a mini-vehicle. Equipped with super ultra-violet ray (UV)-cut thermal insulated green glass (front doors), Emergency Stop Signal, Comfort Flashers (turn signals that stop automatically), and electric automatic retractable door-lock-linked remote control body-colored door mirrors.
June 6	eK Wagon, eK Custom	Mitsubishi Motors	New model UV-reducing glass that cuts out 99% of UV radiation was adopted for the front door windows (not available on the eK Wagon E) (a first for Mitsubishi). Hill Start Assist was adopted (excluding the eK Wagon E and eK Custom T) (a first for Mitsubishi). Equipped with the new generation of MIVEC engine. The INVECS-III (with driver gear shift behavior learning function) CVT (with auxiliary transmission) was adopted. Mitsubishi's original ETACS electronic control system was adopted. Headlight Auto Off, Comfort Flasher, and Variable Intermittent Wiper functions were also adopted. Mitsubishi's original impact safety body, called RISE, was adopted. ABS is standard equipment on all vehicles. The Emergency Stop Signal function was adopted (a first for Mitsubishi). All vehicles achieved the 2015 fuel efficiency standard +20% threshold. eK Wagon G and eK Custom G and T: An interior driving mirror that houses a rear view monitor is standard equipment. An engine start push button and keyless operation system were adopted (a first for Mitsubishi). eK Wagon, eK Custom M, G (2WD vehicles): The Auto Stop & Go (ASG) idling-stop system was adopted (a first for Mitsubishi) and a fuel economy of 29.2 km/L (in JC08 test cycle) was realized. eK Wagon M and G, eK Custom G (4WD vehicles): The Auto Stop & Go system was adopted and a fuel economy of 26.0 km/L was realized. eK Wagon E: Good fuel economy of 25.8 km/L was realized. eK Custom T: Equipped with a turbocharged engine. Good fuel economy of 23.4 km/L was realized. The 2WD vehicle achieved the 2015 fuel efficiency standard +10% threshold, while the 4WD vehicle complies with the 2015 fuel efficiency standard with a fuel economy of 22.6 km/L.

proach warning devices, functions to control unintended acceleration, side and rear vehicle detection alarms, and vehicle swerving alerts.

3.4. Standard vehicles, small vehicles, and mini-vehicles introduced in 2013 by leading Japanese manufacturers and technological trends

The tables above have summarized and described the most important and latest technologies that were incorporated into the standard, small, and mini-vehicles introduced in 2013 by the leading Japanese manufacturers.

Table 13 Mini-vehicles introduced in 2013 by leading Japanese manufacturers and technological trends (cont.).

Release date	Model	Manufacturer	Major details
June 12	Spacia Custom	Suzuki	New model The interior and exterior designs of the Spacia were changed and more exterior colors were added. A front stabilizer and front ventilated disc brakes were adopted. The turbocharged vehicles achieved good fuel economy of 26.0 km/L (2WD vehicle) and 25.0 km/L (4WD vehicle). The NA vehicles also achieved good fuel economy of 27.8 km/L (2WD vehicle) and 26.8 km/L (4WD vehicle). Suzuki Green Technologies such as eNe-CHARGE, new idling stop system, and eco-cool, and TECT were adopted. The vehicles were certified as achieving the 2005 emissions standard 75% reduction level. All models qualified for the eco-car tax exemption by achieving the 2015 fuel efficiency standard +20% threshold.
June19	Alto Lapin Chocolat	Suzuki	New (derivative model) Designed specifically to appeal to the tastes of young women. Premium UV and infra-red (IR)-reducing glass was adopted (on the X grade). Equipped with an eco-drive support function. Equipped with a navigation system that can connect to smart phones (as a manufacturer's option).
July 18	Flair Wagon Custom Style	Mazda	New model Based on the Spacia Custom. The Custom Style XS realized a fuel economy of 27.8 km/L and the Custom Style XT realized a fuel economy of 26.0 km/L (both are 2WD, in JC08 test cycle). Achieved the 2005 emissions standard 75% reduction level. All models qualified for the eco-car tax exemption due to achieving the 2015 fuel efficiency standard +20% threshold.
October 3	Tanto	Daihatsu	Full-model change The interior and exterior designs were changed. The interior upholstery was changed. More exterior colors were added. The front passenger's seat can slide back and forth a longer distance (380 mm). Sliding doors adopted on both sides of the vehicle. The front passenger's seat equipped with a seat reclining lever. Parts such as the hood and front fender are now made from plastic (reduced the weight by 10 kg compared to steel). This also allowed the back door and rear spoiler to be molded as a single piece, which improved the aerodynamic performance and contributed to improved fuel efficiency and handling. Handling was also improved through increased roll stiffness. Hill-climbing transmission control was adopted. The Miracle Open Door with built-in pillars ensures safety. Smart Assist is available on all grades and models. The Emergency Stop Signal was adopted. The shape of the engine pistons was optimized to reduce knocking. The combustion efficiency was improved by raising the compression ratio (from the previous level of 9.0 to 9.5).
November 22	N-WGN, N-WGN Custom	Honda	New model A twin-injection system was adopted for the first time on a Honda mini-vehicle, realizing excellent driving performance and fuel economy. Combining a high-output and high-torque DOHC engine and improved CVT, fuel economy of 29.2 km/L was realized (in JC08 test cycle). The Emergency Stop Signal (ESS) system, Vehicle Stability Assist (VSA) system, and Hill Start Assist (HAS) function are now standard equipment. The City-Brake Active System is available on certain types of vehicles. The side curtain airbag system and front seat i-side airbag system are standard equipment on select model types. The Pedestrian Injury Mitigation Body was adopted to realize better collision safety performance. The vehicles were certified as achieving the 2005 emissions standard 75% reduction level. The NA version of the vehicle achieved the 2015 fuel efficiency standard +20%, while the turbocharged vehicle achieved fuel efficiency performance that exceeded 10%. More than 90% of the entire vehicle is recyclable.

Source: PR materials published by each passenger car manufacturer

This summary covered new models (including derivative models) and full-model-change vehicles.

In 2013, six new (including derivative models) standard and small vehicles, and seven new mini-vehicles were launched. Five standard and small vehicles, and two mini-vehicles were given a full model change (Tables 12 and 13).

Design Trends

Although 2013 was a year in which environmental problems and other issues still loomed as large as ever, it also saw growing emphasis on appealing to customers through attractive design. The growth of the Chinese and emerging markets also had a large impact. Competition is intensifying as the number of new manufacturers in the emerging markets has exploded. Every automaker recognizes the critical role of vehicle design and there is obvious movement on to incorporate design as part of business strategy.

The following sections describe recent vehicle design trends with a focus on vehicles from European manufacturers that are making particular effort to increase appeal through design.

1 Brand Design

One notable trend is that vehicle design is no longer considered as a superficial style that simply improves product appeal. Instead, there are an increasing number of examples of design positioned as an important aspect

Fig. 1 Renault Cycle of Life concept.

Fig. 2 Renault Clio and DeZir.

Fig. 3 Mazda 3 (Axela in Japan).

Fig. 4 Headlights on Audi A8.

of business strategy.

Expressing brand identity is becoming increasingly important for popular car brands as well as premium luxury vehicle brands. Brand identity has become a way of strongly expressing a unified message that defines the character of the brand.

The French automaker Renault has displayed an extremely unique process for unifying the design of its brand. In 2012, Renault demonstrated a brand design concept called The Cycle of Life and unveiled the DeZir. Since then, Renault presented one to two new concept cars every year and brought together all six of these Cycle of Life cars at the 2013 Paris Motor Show (Fig. 1).

This lineup of wide-ranging vehicle models, from small vehicles to utility cars, expressed a world view through a single story. This is a good example of how limited resources can be used for very effective brand building and creating appeal.

This group of concept cars also demonstrated the color direction of the Renault brand and these colors have already started to be applied to mass production vehicles. The new theme color for the Clio (called the Lutecia in Japan) (Fig. 2) is Rouge Flamme (Red), which was shown on the DeZir concept vehicle. In the future, it is predicted that the range of rainbow colors shown on this group of concept cars will eventually be reflected on mass production models as Renault's image colors to evoke a sense of vividness and vigor.

Mazda is the Japanese brand that has unified its design language with a very clear expression. In 2012 the CX-5 crossover SUV and Mazda 6 (the Atenza sedan and wagon) were given full model changes, followed by the Mazda 3 (Axela sedan and 5-door hatchback) in 2013. The styling of all of these vehicles was unified under a theme called Soul of Motion.

The front grilles are all adorned with the signature wing of Mazda and the bodies have a unified sculpted theme that gives the designs a sense of consistency.

The body colors were unified and soul red premium metallic was made the theme color. These vehicles have only been shown in this color at car shows around the world to help convey the emotional image of the Mazda brand. This special color has also been used on the helmets of players for the professional baseball team in Hiroshima, the Toyo Carp, to further expand brand appeal.

Audi has made technical innovation and advancement the distinguishing characteristic of its brand and has been putting a great deal of effort into advancing the latest technologies. One example of these efforts is the changes made to the headlights when the A8 was given a facelift (Fig. 4). The so-called Matrixbeam LED headlights have a variable high beam suitable for all weather environments. A marker light that illuminates pedes-

Fig. 5 Peugeot 308.

Fig. 6 Ford Vignale concept.

trians in the dark and sequential LED turn signals that appear to be flowing light were also adopted. The EU ended up making regulatory revisions at the same time that this new technology was introduced to the market.

Models from Japanese automakers are also being designed with a unified expression for the front faces. Toyota has announced a design theme called "keen look", Nissan is using a theme called V Motion and has adopted a so-called "boomerang lamp" design. Honda has adopted the Solid Wing Face design theme. These unified designs are starting to be applied globally.

The French automaker Peugeot presents an example that runs opposite to this unified design trend. After originally unifying the front face design with a distinctive, single large grille and almond-shaped headlights that slanted upwards at the corners, the new model 308 (Fig. 5) has a universal, two-level grille and the front face was changed to have a more reserved and conservative configuration.

2 Exterior Design

With exterior design, the eye tends to be attracted to surfaces and graphics. In the global market, the important proportions of the vehicles are also evolving.

The Chinese market is becoming more and more active, so popular vehicles from U.S. brands are incorporating the trends of premium European vehicles and pre-

Fig. 7 Audi A8L.

senting designs that reflect the preferences of the people in this market. Ford emphasized a premium luxury feel in its Vignale concept (Fig. 6) as an indicator of the future direction of its Mondeo model.

Even vehicles from GM's European brand Opel (the Buick brand in China) are increasing in size in consideration of the Chinese market.

In the premium European sedans, the interior comfort of the rear seats is given special emphasis, resulting in a remarkable expansion in vehicle length. Long wheelbase (LWB) versions of vehicles have become mainstream in the Chinese market. For example, the wheelbase of the Audi A8L (Fig. 7) was increased 130 mm and now exceeds 3,100 mm. This is reaching a level that most Japanese have difficulty understanding.

One important point with respect to vehicle size, such as the size of small B-segment hatchbacks in the global market, is that Japanese vehicles have peaked at a width of 1,700 mm (i.e., the width of the 5-series body). However, in other countries, this same class of vehicles is 30 to 50 mm wider. Consequently, this has created a large gap in the dynamism of the handling performance and also in the impression given by the external appearance.

One trend that is currently being pursued to improve the fuel efficiency of vehicles is to decrease vehicle height. European brands in particular are straightforwardly adopting vehicles with wide and low proportions. This trend is even spreading from the E-segment to the D-segment in the form of more coupe-like sporty sedans (for example the Mercedes-Benz CLA) (Fig. 8).

The new model Volkswagen (VW) Golf VII (Fig. 9) follows in the styling image of its predecessor model, but its proportions are wider and lower and it has evolved to have an even more high-performance frame.

European vehicles are changing the proportions of the vehicle frames without changing the basic styling image. However, Japanese vehicles are just the opposite. It has

Fig. 8 Mercedes-Benz CLA.

Fig. 9 Golf VII.

become common practice for the same vehicle frames to be kept, while the styling is changed. This can be said to be a major difference between Japanese and European vehicles.

3 Interior Design

3. 1. Customized designs

The use of decorative parts, as seen on Mini and Smart models, for interior and exterior coordination and as a method of customization is being widely adopted, even by popular European brands. Separate vehicle grade specifications have been created that are tailored to individual brand characteristics and customer preferences. Part configurations have also been systematized so that materials and colors can be changed and different grades can be separated effectively (for example, the Renault Clio) (Fig. 10).

The same mechanisms and manufacturing methods are increasingly being used by multiple automakers. For example, the air conditioner outlets used on the entire lineup of Mercedes-Benz vehicles have a unified round shape, but the mechanism inside is the same as the one used by Audi. There is increasing collaboration between mega parts suppliers and multiple automakers and this is accelerating the centralization and efficiency of these

Fig. 10 Interior of Renault Clio.

Fig. 11 Interior of Mercedes-Benz S class.

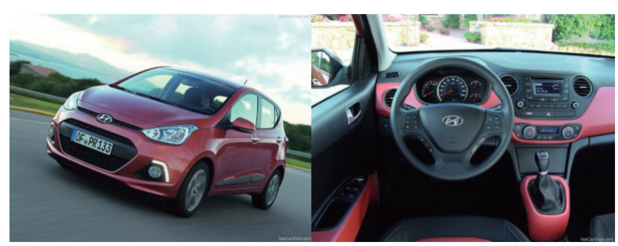

Fig. 12 Hyundai i10.

trends.

3. 2. Designed for all five senses

The design of the new S class from Mercedes-Benz (Fig. 11) sought to appeal not only to the sense of sight, but also to the senses of sound, smell, and touch.

A design expression that appeals not only to the eyes, but also to the other feelings and emotions of human beings is a theme that will become increasingly important in the future.

In Europe the number of models using high-quality materials for parts touched by customers' hands is increasing, even in the compact A-segment. Vehicles, such

Fig. 13 Liquid-crystal meters in Mercedes-Benz S class.

Fig. 14 Liquid-crystal meters in BMW i3.

as the i10 from Hyundai (Fig. 12) use real leather for parts such as the steering wheel and shift lever knob.

3. 3. Liquid crystal dashboard meters

The adoption of large-sized liquid-crystal panels for dashboard meters has expanded, and the search has already begun for a display method to use on new panels. The preferred way of expressing dashboard meters has divided into two camps: one that presents conventional meters using graphics (for example the Mercedes-Benz S) (Fig. 13) and one that expresses meters in forms more like that seen on mobile devices (for example the BMW i3) (Fig. 14).

4 New Design Hints

The BMW i Series vehicles (Figs. 15 and 16) have adopted a new power plant that is looking ahead to the future and even the materials and production method that are used were changed significantly from those used up until now.

Fig. 15 BMW i3.

Fig. 16 BMW i8.

The structure is a full carbon monocoque body with plastic exterior panels that are attached using adhesives. The styling of this vehicle series resembles a thin skin floating on the vehicle frame. The differences between function and structure were actively expressed in this styling.

Even in the interior design, a new premium feeling was orchestrated through expressive techniques similar to furniture. Wood and bast fibers (such as kenaf, hemp, and flax) were used as new materials to help bring the texture of recycled materials to the forefront and express a groundbreaking natural, premium quality.

As automakers face increasing demands to further reduce the environmental impact of vehicles and reduce weight, an evolution in vehicle design is starting to occur through changes in materials and manufacturing methods. Engineering and styling design are fusing together and new possibilities are being created.

Vehicle manufacturing in which everything, including the manufacturing method itself, has been changed is a risky strategy with no guarantee of success, but it is a strategy that is being undertaken with the strong resolve to change the world. The difference between this and the approach of Japanese automakers that have continuously pursued results and efficiency are clearly expressed in vehicle styling design.

Body Structures

1 Technological Trends

It has been reported that 20% of CO_2 emissions, which is one of the main causative agents of global warming, come from vehicles. Consequently, there is an urgent need to reduce the amount of CO_2 emissions from vehicles by improving fuel efficiency. Up until now, automakers have introduced a variety of technologies to improve fuel efficiency, but mainly in developed nations.

However, since the population of the world is increasing mostly in Asia and Africa, the quantitative epicenter of the global vehicle market is likely to shift to China and emerging nations in terms of demand and supply. In the future, it will be essential to improve vehicle fuel efficiency and reduce CO_2 emissions in these markets as well.

In the field of automotive technology, automakers in developed nations have expanded the use of electricity in vehicles through fully electric vehicles and HEVs. In contrast, vehicles in emerging nations still mostly use gasoline and diesel fuels, creating a wide range of demand across both markets. High-efficiency vehicles that can meet the demands for a diverse selection of powertrains and vehicle forms must be introduced to the market quickly. To accomplish this, a variety of specifications need to be designed in advance and body structures are increasingly being configured to combine together with a platform (P/F) as a module. This concept has penetrated the engineering divisions of automakers in recent years. In 2013, Volkswagen launched the Golf VII, which uses the Modular Transverse Matrix (MQB) P/F. Toyota has adopted the Toyota New Global Architecture (TNGA) P/F, and Nissan has developed the Common Module Family (CMF) P/F. Every major automaker has begun to deploy these kinds of vehicle P/F.

The practical application of primary safety technologies is also making progress and 2013 saw the adoption of collision mitigation braking systems on a wide range of models. In the future, there are plans to add these systems as an evaluation item to New Car Assessment Programs (NCAP), including JNCAP in Japan. Further development of this technology to realize autonomous driving is expected to accelerate in the future. In contrast, laws and regulations concerning secondary safety technologies are still being strengthened. The small overlap test (SOT) has been added to the protocols of the Insurance Institute for Highway Safety (IIHS) in the U.S., necessitating substantial body reinforcements.

Consequently, the major issue for automakers related to the body is how to reduce weight to improve fuel efficiency while reinforcing the body to improve collision safety. Therefore, the next section will take a look back at the body technology trends for passenger cars that were launched in 2013 from this standpoint.

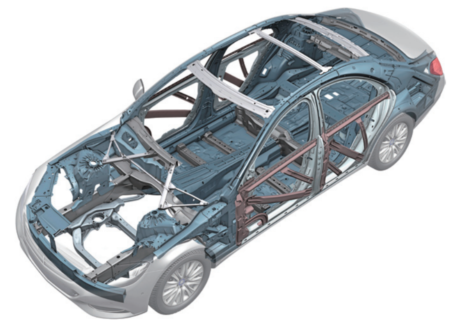

Fig. 1 Mercedes-Benz S class body structure (source: Mercedes-Benz Japan website).

Fig. 2 BMW i3 passenger cell made from CFRP (source: BMW website).

2 Weight Reduction

Reducing vehicle weight contributes to an overall improvement in driving performance and is a major factor in improving fuel efficiency. It can also increase driving appeal in conjunction with optimization of the weight distribution and stiffness balance. If the weight is reduced, the required kinetic energy decreases and the powertrain can be downsized. It also becomes possible to reduce the brake capacity and the capacity of the fuel tank. In other words, reducing weight leads to a positive spiral of beneficial side effects. In the case of collision safety as well, a decrease in energy decreases the required load bearing force of the body frame, helping to reduce weight through the use of thinner body members. Reducing vehicle weight is now the unwavering direction in which vehicle technology is advancing, regardless of laws and regulations.

2. 1. Body structure

In addition to conventional monocoque bodies using steel sheets, multi-material body frames made from steel sheets and aluminum have now begun to be applied in earnest, starting with the Mercedes-Benz S class (Fig. 1). The BMW i3 (Fig. 2) is composed of an aluminum P/F frame with a CFRP cabin frame. The adoption of vehicle frames composed of multiple materials is continuing to expand.

2. 2. Steel sheets

Steel sheets still compose the largest proportion of the body. Higher strength steel is being applied to a larger number of portions to comply with collision performance requirements that become stricter every year.

One of the current trends for increasing the strength of steel sheets is the expanded use of hot-stamped material. In weight terms, the Golf VII uses hot-stamped 1,500 MPa-class materials over 28% of the white body. A reduction in the total number of parts was achieved by integrated molding of complex-shaped parts, taking advantage of the high formability and reduced weight of this material due to its higher strength. In the hot stamping process, a steel sheet is heated to approximately 900℃ and then stamped directly using a die. This technology achieves high strength by turning the internal structure of the steel into a martensite single-phase structure through rapid cooling. However, since the heating and cooling processes take time, productivity is lower than cold stamping. However, there are significant advantages to hot stamping, such as the forming of stronger steel than that obtained through cold stamping, a high degree of precision that almost eliminates spring back, and lower die investment due to consolidation of the forming stages. Furthermore, partial heating of the forming die allows for a partial tempering treatment to be carried out through quenching control, lasers, and high-frequency induction heating. This makes it possible to intentionally create low-strength, high-ductility parts, which in turn makes it possible to obtain different material strength characteristics within the same parts. This stamping technology achieves the required performance without increasing the number of parts or weight. This is true even when the required performance differs depending on the portion of the part, such as center pillars, and when a high level of elongation is required. The weight reduction potential of hot-stamped materials is greater than that of cold-stamped materials.

However, increasing the strength of cold-stamped materials can maintain higher productivity through the utilization of existing equipment and facilities. For example, the Nissan X-Trail uses cold-stamped 980 MPa-class steel sheets for the front and center pillars and the Suzuki Spacia uses cold-stamped 1,180 MPa-class steel sheets for the front side members. This reduces the weight of these vehicles while maintaining body strength. To achieve even further weight reductions, steel sheets must continue to advance and evolve toward even higher strength and formability. There are strong expectations for improvements in workability and delayed fracturing resistance, innovations in stamping methods, and more precise forming analysis technologies.

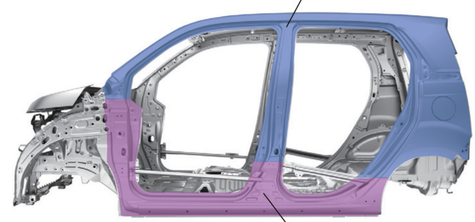

Fig. 3 Tailored blank outer panels of Honda N-WGN.

2. 3. Variable sheet thickness technologies

Subdividing the different levels of required performance, even on the same part, and then setting the sheet thickness and steel grade accordingly is another way to reduce weight. The Nissan Skyline uses tailored blank technology with large differences in material strength. Tailored blanks formed using 1,180 MPa-class and 440 MPa-class steel sheets are used for the center pillars. Weight is reduced by using hot-stamped materials to reinforce certain parts while addressing the different levels of required performance in accordance with the portion. The Honda N-WGN uses tailored blank technology to apply 780 MPa-class steel sheets and 340 MPa-class steel sheets for the outer panels (Fig. 3). The structure of these outer panels was streamlined by increasing strength and disusing the stiffener to reduce weight. Furthermore, tailor rolled blank technology continuously varies the thickness of the steel sheet by re-rolling coil materials. VW used this technology for the hot-stamped materials in the center pillars and floor cross members of the Golf VII. This was done to increase efficiency and reduce weight by optimizing the sheet thickness within the same part. By clarifying the required performance for each portion in this way, the concept of optimized sheet thickness is likely to continue to accelerate in the future.

2. 4. Continuous joining technology

As described in Sections 2.2 (steel sheets) and 2.3 (variable sheet thickness technologies), reducing thickness while maintaining strength results in lower weight but also reduces stiffness. It is not possible to reduce the target stiffness of the body because of the adverse effects on handling. Consequently, one means of increasing stiffness to compensate for the reduced thickness of members is to expand the application of continuous joining. Conventional spot welding joins together pieces at a single point. In comparison, continuous joining creates a line or surface joint, or creates joins with an interval of 10 to 15 mm between points. The definition of continuous joining used here also includes shortened-pitch spot joints that obtain characteristics that are close to those of continuous joining. In the Lexus IS, the line length of the structural adhesive was increased to 25 m and LSW was used to realize shortened-pitch spot joints of 12 mm, which is not possible with spot welding. In the Mazda Axela as well, the number of spot welds on the door openings and around the floor were increased and structural adhesive was applied. This resulted in a lighter and stiffer body. In addition to improving stiffness, this use of adhesives helps the joints between surfaces to disperse stress, which in turn improves fatigue strength and fracturing performance in a collision. This should also increase the amount of energy that is absorbed. The application of adhesives to mating surfaces on the boundary between the outside and inside of the vehicle cabin should also improve waterproofing as well as noise, vibration, and harshness (NVH). However, expanding the use of adhesives to mass production creates other issues, such as application quality, precision control, anti-shower resistance prior to coating, and the aging of the adhesive material. Therefore, further advancement of application tools and the development of improved materials are expected.

2.5. Aluminum

The substitution of different materials for conventional ones is essential to achieving significant weight reductions. At the 2014 Detroit Auto Show, the Ford F-150 pickup truck for North America was announced with an aluminum body that decreased the weight of the entire vehicle by 318 kg. Since the specific bending rigidity of aluminum is twice that of steel, a weight reduction of 50% may be achievable when aluminum is applied to stiff members. One issue with the expansion of aluminum in vehicles is the increase in material costs. However, aluminum is the clear material of choice for vehicle members from a comprehensive standpoint of cost efficiency, the absolute weight reduction achieved compared to other technologies, and the increased marketability of vehicles with a higher aluminum content. For example, weight distribution and a low center of gravity are important factors that determine vehicle handling, and aluminum grants certain advantages over steel for these factors. On premium brand vehicles the application of aluminum is becoming increasing popular for body closure parts such as hoods, fenders, doors, and tailgates as an effective means of attaining a good weight distribution, low center of gravity, and low inertia. The combination of different materials, such as steel and aluminum, is now occurring more often as manufacturers attempt to optimize the materials for each portion of the body. In locations where these different materials are joined together, countermeasures against electrolytic corrosion and thermal contraction due to the different linear expansion coefficients are necessary. Aluminum is used for 14% of the white body of the Mercedes-Benz S class, mainly the roof, front damper housing, and rear damper housing. It was thought that this will contribute to a lower center of gravity, improved weight distribution between the front and rear of the vehicle, and improved body stiffness. When steel sheets are joined to aluminum members, adhesive is used both for joining and as an insulator, and members are also mechanically fastened together using self-piercing rivets (SPR) or flow drill screws (FDS).

2.6. Plastic

Plastic has an even lower specific gravity than aluminum and also a low specific rigidity. It also allows more complicated designs to be expressed when used for the outer panels of the vehicle. Plastic can be integrally molded into complex shapes, reducing the number of parts, and lowering both costs and weight. On the Daihatsu Tanto, these characteristics of plastic were utilized to form outer panel parts such as the hood, fenders, fuel cap, and slide rail covers. Plastic was also used for integral molding of the spoiler and license plate garnish on the back door, as well as for integral molding of inner and interior trim parts. The use of plastic reduced both the number of parts and weight. A plastic back door was also adopted for the Nissan X-Trail, reducing the weight for the automatic opening and closing system as a secondary effect.

2.7. CFRP

Since CFRP has a high specific rigidity and specific

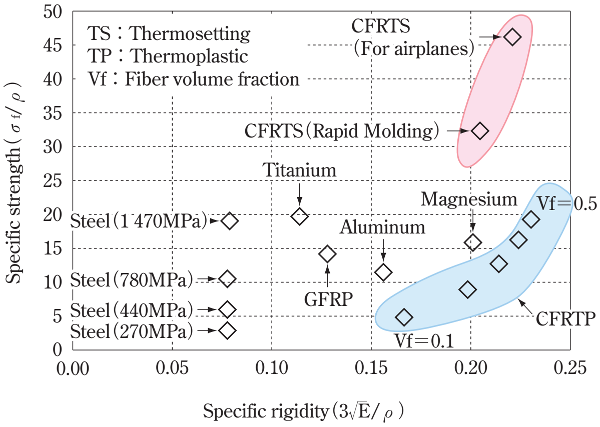

Fig. 4 Comparisons of specific strength and specific rigidity of various structural materials (source: March 2006 issue of JAMA MAGAZINE).

strength, it has a high weight reduction potential (Fig. 4). However, due to high material cost long machining times, its application to body frames has been limited to low-volume production vehicles, such as sports cars and luxury vehicles. However, when BMW reviewed the material supply system for the i3 model, it was able to shorten the forming time by using resin transfer molding (RTM) to combine multiple carbon-fiber preform materials within a die oriented optimally for the required performance of each portion. As a result, the parts and processes were consolidated significantly and it became possible to produce a volume of 10,000 vehicles a year. In the future, research into manufacturing methods with higher productivity will be promoted and if thermoplastic CFRP can be put into practical use, then application of this material will be significantly expanded.

3 Collision Safety

Ensuring collision safety performance is essential when considering the body structure. The general way of thinking about conventional head-on collisions and off-

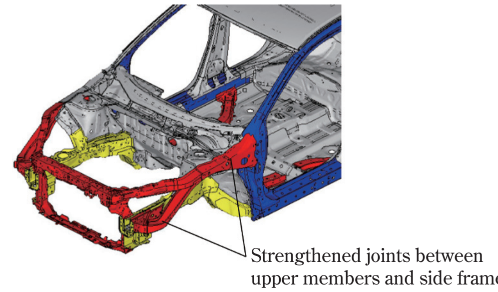

Fig. 5 Next-generation load dispersion frame of Honda Accord (source: material published by IABC in 2012).

set collisions was that the front-side frame of the vehicle would efficiently absorb the energy of the collision and then this reaction force would be dispersed through multiple members of the frame to inhibit deformation of the cabin and protect the vehicle occupants. However, in the SOT that was added to the protocols of the IIHS in 2013, the collision barrier does not hit the front-side frame and so a conventional vehicle frame is unable to sufficiently absorb the energy. As a result, the general response from automakers has been to reinforce parts around the cabin, such as the front pillars, side sills, and lower dashboard, leading to a significant increase in weight. In the Honda Accord, the upper member, which is on the outside of the side frame, is joined solidly to the side frame (Fig. 5) and the absorbed energy is then dispersed to the side frame. As a result, weight increases were significantly limited, it received a GOOD rating, and was classified as a TOP SAFETY PICK+ by the IIHS. In the future it is predicted that automakers will continue to raise survivability and apply technologies such as this toward collision safety from all directions. Finding ways to efficiently achieve both a reinforced body and lower weight, as well as to contribute to the realization of a low-carbon society is an urgent mission.