MOTORCYCLES

Overall Trends

1 Introduction

The number of motorcycles produced in Japan in 2015 declined 13% compared to that in 2014. Production of motorcycles in Japan had fallen for three years in a row since 2010 and there were expectations for a turnaround after a temporary increase in production in 2014, but in the end both domestic shipments and exports declined in 2015, as did production volume.

2 Production and Demand Trends

2. 1. Production

Figure 1 shows that the number of motorcycles produced in Japan in 2015 decreased 13% compared to 2014 down to 520,000 units. Motorcycle exports were down 10% to 420,000 units mainly due to a decrease in demand in North America and shipments in Japan were also down by 10% to 370,000 units mainly due to the decrease in demand for class 1 motor-driven cycles (mopeds).

2. 2. Demand in Japan

Fig. 2 shows that when demand for motorcycles in Japan in broken down according to the engine displacement, all of the different classes of motorcycles experienced decreased demand in 2015. Class 1 motor-driven cycles (mopeds) had an especially large decrease of 15%, while the class 2 motor-driven cycles maintained roughly the same level of demand as in 2014. Total demand for all classes decreased by 10% in comparison to 2014, down to 374,000 units.

2. 2. 1. 50 cm^3 or less (class 1 motor-driven cycles)

In 2015, demand for this class fell by 15% to 194,000 units compared to the previous year and this was the fourth consecutive year of decline in demand. The decrease in 2015 was also the largest such single year decrease during these past four years.

2. 2. 2. 51 to 125 cm^3 displacement motorcycles (class 2 motor-driven cycles)

In 2015, the demand for all other classes decreased, but demand for this class stayed at roughly the same level as in 2014 at 95,000 units.

2. 2. 3. 126 to 250 cm^3 displacement motorcycles (mini-sized motorcycles)

The demand for this class increased significantly in 2014, but in 2015 it decreased by 7.5% compared to the previous year, down to 49,000 units.

2. 2. 4. 251 cm^3 or higher displacement motorcycles (small-sized motorcycles)

The demand for this class also increased significantly

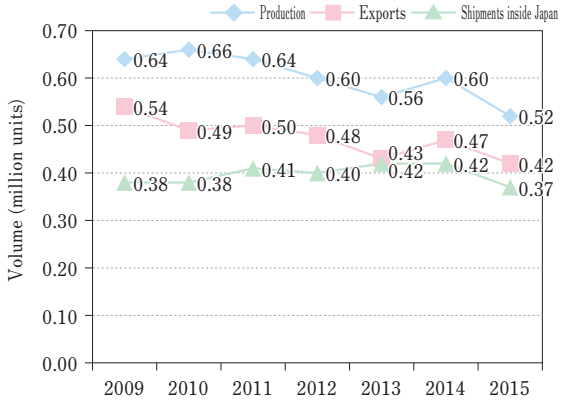

Fig. 1 Trends in Motorcycle Production, Exports, and Shipments Inside Japan

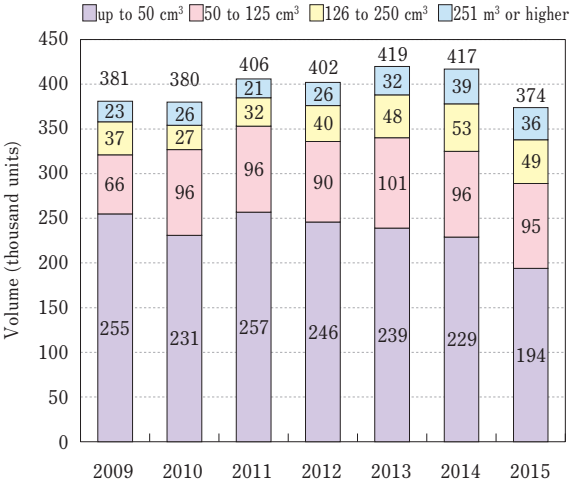

Fig. 2 Shipments Inside Japan based on Engine Displacement

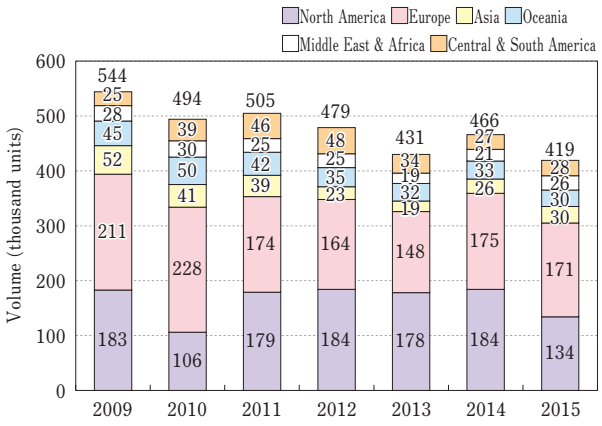

Fig. 3 Number of Units Shipped to Each Overseas Market

in 2014, but in 2015 it showed the same trend as the mini-sized motorcycles and decreased by 7.6% compared to the previous year, down to 36,000 units.

2. 3. Exports

Figure 3 shows that motorcycle exports in 2015 decreased by 10%, down to 419,000 units, compared to the previous year. The number of motorcycle exports has been decreasing for several years now, and there were expectations for a turnaround after a temporary increase in exports in 2014, but the large decrease in exports to North America of 27% meant that total motorcycle exports from Japan have fallen all the way back to the level recorded in 2013.

2. 3. 1. North America

In 2015, exports to North America fell significantly by 27% to 134,000 units.

The scale of this decrease in export volume to North America is on the same scale as that of the overall decrease in export volume.

2. 3. 2. Europe

Motorcycle exports to Europe in 2015 remained at largely the same level as the previous year, 171,000 units. As a result of the significant decline in exports to North America, the European market has now become the largest receiver of Japanese motorcycle exports (accounting for 40% of the total export volume).

2. 3. 3. Asia

In 2015, exports to Asia rose by 13% compared to the previous year, to 30,000 units, marking a second straight year of increases.

2. 3. 4. Oceania

Exports to Oceania in 2015 decreased by 9% compared to the previous year to 30,000 units.

2. 3. 5. The Middle-East and Africa

In 2015, exports to the Middle East and Africa rose by 24% compared to the previous year to 26,000 units and this was the second straight year they increased.

2. 3. 6. Central and South America

Exports in 2015 to Central and South America re-

Table 1 Main New Motor-driven Cycle Models Introduced in 2015

Month of launch	New	Modified	Manufacturer	Name of model	Characteristics
January		○	Honda	CB1100EX<ABS>	Air-cooled/4-stroke/inline 4-cylinder
	○		Honda	Tact, Tact Basic	Water-cooled/4-stroke/single-cylinder OHC/2-valve/FI
		○	Honda	CBR1000RR.SP Champion Special	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Suzuki	Bandit 1250S ABS	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
February		○	Honda	Little Cub Special	Water-cooled/4-stroke/single-cylinder OHC/2-valve/FI
		○	Honda	NC750S Special Color	Water-cooled/4-stroke/2-cylinder OHC/4-valve/FI
		○	Honda	CB400 SUPER FOUR Special Edition	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Honda	CB400 SUPER BOL D'OR Special Edition	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Honda	CB1300 SUPER FOUR E package Special Edition	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Honda	CB1300 SUPER BOL D'OR E package Special Edition	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Yamaha	Cygnus X	Air-cooled/4-stroke/single-cylinder SOHC/4-valve/FI
	○		Yamaha	MT-09 TRACER ABS	Water-cooled/4-stroke/3-cylinder DOHC/4-valve/FI
		○	Yamaha	XVS950CU BOLT-C	Air-cooled/4-stroke/V2 SOHC/4-valve/FI
		○	Kawasaki	Ninja ZX-6R (Racing model)	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Kawasaki	Ninja 400, Ninja 400 Special Edition	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
March	○		Honda	Dio110	Air-cooled/4-stroke/single-cylinder OHC/2-valve/FI
		○	Honda	NM4-01, NM4-02	Water-cooled/4-stroke/2-cylinder OHC/4-valve/FI
		○	Honda	Gold Wing FC6C	Water-cooled/4-stroke/6-cylinder OHC/2-valve/FI
		○	Yamaha	MAXAM CP250	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
		○	Yamaha	MT09 ABS	Water-cooled/4-stroke/3-cylinder DOHC/4-valve/FI
		○	Yamaha	MT07 ABS	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
	○		Suzuki	Address 110	Air-cooled/4-stroke/single-cylinder SOHC/2-valve/FI
	○		Kawasaki	Ninja 250SL	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
		○	Kawasaki	W800 Limited Edition	Air-cooled/4-stroke/2-cylinder SOHC/4-valve/FI

Table 1 Specifications of Engines Equipped on New 2015 Models

Month of launch	New	Modified	Manufacturer	Name of model	Characteristics
April	○		Yamaha	YZF-R1	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Yamaha	YZF-R25 ABS	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
		○	Yamaha	YZF-R3 ABS	Water-cooled/4-stroke/2-cylinder DOHC/5-valve/FI
		○	Yamaha	TRICITY 125 ABS	Water-cooled/4-stroke/single-cylinder SOHC/2-valve/FI
	○		Kawasaki	Ninja 250SL	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
		○	Kawasaki	W800 Limited Edition	Air-cooled/4-stroke/2-cylinder SOHC/4-valve/FI
May		○	Honda	PCX, PCX150	Water-cooled/4-stroke/single-cylinder OHC/2-valve/FI
		○	Yamaha	Gear BX50, BX50N, BX50SJ	Water-cooled/4-stroke/single-cylinder OHC/3-valve/FI
		○	Suzuki	Let's Basket	Air-cooled/4-stroke/single-cylinder SOHC/2-valve/FI
		○	Suzuki	Address V50	Air-cooled/4-stroke/single-cylinder SOHC/2-valve/FI
June		○	Honda	Lead 125	Air-cooled/4-stroke/single-cylinder OHC/2-valve/FI
		○	Kawasaki	Ninja 400 ABS Limited Edition	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
		○	Kawasaki	VULCAN S, VULCAN S ABS	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
July	○		Honda	RC213V-S (began accepting orders)	Water-cooled/4-stroke/V4 DOHC/4-valve/FI
		○	Yamaha	YZF-R25 Movistar Yamaha MotoGP Edition	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
	○		Suzuki	GSX-S1000 ABS, GSX-S1000F ABS	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Suzuki	Burgman 200	Water-cooled/4-stroke/single-cylinder SOHC/4-valve/FI
	○		Kawasaki	KX100	Water-cooled/2-stroke/single-cylinder Cab
August	○		Honda	Benly, Benly Pro	Air-cooled/4-stroke/single-cylinder OHC/2-valve/FI
		○	Yamaha	YZ250X, YZ450F, YZ250F	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
	○		Yamaha	E-VINO	Electric motor
		○	Suzuki	Skywave 650LX	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
		○	Kawasaki	KX250F	Air-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
September		○	Honda	CRF250R, CRF450R	Water-cooled/4-stroke/single-cylinder OHC/4-valve/FI
		○	Yamaha	Majesty S XC155	Water-cooled/4-stroke/single-cylinder SOHC/4-valve/FI
		○	Yamaha	WR250R, WR250X	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
October	○		Honda	Giorno	Water-cooled/4-stroke/single-cylinder OHC/2-valve/FI
	○		Yamaha	MT-03, MT-25	Water-cooled/4-stroke/2-cylinder DOHC/5-valve/FI
		○	Yamaha	Jog CE50	Water-cooled/4-stroke/single-cylinder OHC/3-valve/FI
		○	Yamaha	Vino XC50D, Vino Molfe XC50H	Water-cooled/4-stroke/single-cylinder OHC/4-valve/FI
November		○	Honda	Gold Wing	Water-cooled/4-stroke/horizontally opposed 6-cylinder SOHC/2-valve/FI
		○	Yamaha	YZ450FX, YZ250FX	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
	○		Yamaha	Cygnus X, XC125SR	Air-cooled/4-stroke/single-cylinder SOHC/4-valve/FI
	○		Kawasaki	Ninja H2R	Water-cooled/4-stroke/4-cylinder DOHC/4-valve/FI
		○	Kawasaki	Ninja 250, ABS KRT Edition	Water-cooled/4-stroke/2-cylinder DOHC/4-valve/FI
December		○	Honda	CBR250R, CBR250R<ABS>Special Edition	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
		○	Honda	CB250F Special Edition	Water-cooled/4-stroke/single-cylinder DOHC/4-valve/FI
	○		Honda	CRF1000 Africa Twin	Water-cooled/4-stroke/2-cylinder OHC/4-valve/FI
		○	Yamaha	TRICITY 125 ABS	Water-cooled/4-stroke/single-cylinder SOHC/2-valve/FI
		○	Yamaha	VMAX	Water-cooled/4-stroke/V4 DOHC/4-valve/FI
		○	Yamaha	SR400 60th Anniversary	Air-cooled/4-stroke/single-cylinder SOHC/2-valve/FI
		○	Suzuki	VanVan 200	Air-cooled/4-stroke/single-cylinder SOHC/2-valve/FI

mained at nearly the same level as the previous year at 28,000 units. This appears to have put a temporary halt to the two year decline in export volume.

3 Product and Technological Trends

3. 1. Product trends

Table 1 lists some of the representative models of motorcycles launched in Japan in 2015. New models on the market include class 1 motor-driven cycles such as the Honda Tact, Giorno, and Benly, the Yamaha E-Vino, and the Suzuki Address V. New models in the mini-sized motorcycles class included the Honda Dio110, Yamaha Cygnus X and MT-25, the Suzuki Address 110, and Kawasaki Ninja 250SL. Among new models in the small-sized motorcycle class, Honda announced the launching of the RC213V-S and CRF1000L Africa Twin, the Yamaha MT-03 and MT-09 Tracer ABS went on sale and the launch of the YZF-R1 racing-based vehicle was also announced, while Suzuki launched the Bandit 1250S and GSX-S1000 ABS, and Kawasaki debuted a new model of the Ninja H2R with circuit racing specifications.

3. 2. Technological trends

Manufacturers are focusing on making class 1 and class 2 motor-driven cycles more environmentally-friend-

Table 1 Specifications of Engines Equipped on New 2015 Models

Manufacturer	Name of model	Engine type	Displacement [cm^3]	Bore [mm]	Stroke [mm]	Compression ratio	Max. output [kW/rpm]	Max. torque [Nm/rpm]
Honda	Dio110	Air-cooled/4-stroke/single-cylinder OHC/2-valve	108	50.0	55.1	9.5	6.6/7 500	9.3/5 500
	CRF1000 Africa Twin	Water-cooled/4-stroke/2-cylinder OHC/4-valve	998	92.0	75.1	10.0	68.0/7 500	95.0/6 000
	RC213V-S	Water-cooled/4-stroke/V4 DOHC/4-valve	999	81.0	48.5	13.0	117/ 11 000	102.0/10 500
Yamaha	N-MAX	Water-cooled/4-stroke/V4 DOHC/4-valve	124	52.0	58.7	11.2	9.0/7 500	12.0/7 250
	YZF-R1	Water-cooled/4-stroke/4-cylinder DOHC/4-valve	998	79.0	50.9	13.0	147.1/13 500	112.4/11 500
Suzuki	Address 110	Air-cooled/4-stroke/single-cylinder SOHC/2-valve	112	51.0	55.2	9.3	6.7/8 000	8.6/6 000
	GSX-S1000	Water-cooled/4-stroke/4-cylinder DOHC/4-valve	998	73.4	59.0	12.2	107.0/10 000	106.0/9 500
Kawasaki	Ninja 250SL ABS	Water-cooled/4-stroke/single-cylinder DOHC/4-valve	249	72.0	61.2	11.3	21.0/9 700	22.0/8 200
	Ninja H2R	Water-cooled/4-stroke/4-cylinder DOHC/4-valve	998	76.0	55.0	8.3	228/14 000	165/12 500

Fig. 1 External Appearance of Dio 110

Fig. 2 External Appearance of CRF1000L Africa Twin

Fig. 3 External Appearance of RC213V-S

ly by adopting technologies that improve the fuel efficiency and reduce weight, while also introducing and adopting a common platform for use on multiple models. They are also adopting a common platform for cycles in the small-sized motorcycle class and increasing the number of these models. At the same time, manufacturers are announcing high-performance models with superchargers mounted on them in pursuit of even higher performance. These high performance models have been attracting a lot of attention for other features as well, such as traction control to transmit the driving force down to the road surface more efficiently, as well as the application of new materials, such as carbon fiber reinforced plastic (CFRP), titanium, and magnesium in an all-out effort to try and reduce the weight of the motorcycles even further.

Fig. 4 External Appearance of N-MAX

Engines

1 Technological Trends in Japan

1. 1. Overview

Table 1 lists the specifications of the engines installed on the major new motorcycle models launched by Japanese manufacturers in 2015.

In the small-sized motorcycle class, combustion was improved, loss was reduced, and idling stop technology was adopted as environmental performance remains a major focus. Engines that achieve both good fuel efficiency and driving performance are being turned into an engine platform in an effort to help mature the technologies and apply it to multiple different motorcycle models.

A similar trend is seen in the large-size motorcycle class where engines designed in the pursuit of improved handling and feel are also being turned into an engine platform, and the number of different models is increasing. At the same time, motorcycle manufacturers are announcing circuit racing bikes with specifications for use on public roads, the adoption of new materials to help

Fig. 5 External Appearance of YZF-R1

Fig. 6 External Appearance of Address 110

Fig. 7 External Appearance of GSX-S1000

Fig. 8 External Appearance of Ninja 250SL

Fig. 9 External Appearance of Ninja H2R

further reduce vehicle weight, and high-performance models that are attracting a lot of attention.

1. 2. Trends of each manufacturer

1. 2. 1. Honda Motor Co., Ltd.

(i) Dio 110 (Fig. 1): This vehicle is equipped with an eSP engine that employs advanced technologies, such as an offset cylinder, an ACG starter, and a wide array of low-friction technologies, to realize a fuel efficiency value of 57.9 km/L in the steady-state level-ground driving test conducted at a speed of 60 km/h. In addition, the combustion efficiency was also improved so that the maximum output value could be raised to 6.6 kW, a 6% improvement compared to the previous model, achieving both superior fuel efficiency and powerful driving performance.

(ii) CRF1000L Africa Twin (Fig. 2): This vehicle is equipped with a water-cooled, four stroke, OHC, 4-valve, 2-cylinder engine that provides a feeling of rear wheel traction and a pleasant twin-engine pulse sensation. A compact package was achieved thanks to the adoption of a 4-valve Unicam head design and a semi-dry sump lubrication system. In an effort to realize reduced vibrations and a deep engine sound with good response, a 270° phased crankshaft and biaxial primary balance shafts were adopted. Honda's unique Dual Clutch Transmission (DCT) will be available as an option on this vehicle, and it is equipped with the standard manual mode, as well as two automatic modes: D mode and S mode. This DCT also has a G switch to reduce the amount of clutch slip during gear changes, as well as incline detection, which allows the gear shift pattern to be adapted depending on the grade of any incline.

(iii) RC213V-S (Fig. 3): This vehicle is based on the RC213V Moto GP-class competitive racing bike, with only a subset of the specifications changed to make it legal to drive on public roads (a coil spring system replaces the pneumatic valve in the camshaft gear train structure, and the seamless transmission was changed to a conventional system). It has inherited most of the specifications of the RC213V to thoroughly ensure the concentration of vehicle mass and reduce friction, as well as all key aspects in manufacturing that set it apart from ordinary mass production models. These include overwhelming differences in the weight and precise machining of the components, plus the expert skills and advanced control technologies required in manufacturing.

1. 2. 2. Yamaha Motor Co., Ltd.

(i) N-MAX (overseas model) (Fig. 4): The N-MAX is powered by a compact liquid-cooled engine developed under Yamaha's Blue Core concept that focuses on high-efficiency combustion, high cooling performance, and reduced power loss. This engine uses variable valve actuation (VVA) technology that can switch the air intake valve operation between the low- and medium-speed sides and the high-speed side over 6,000 rpm to provide both pleasant acceleration characteristics and good fuel efficiency. Yamaha's all-aluminum DiASil cylinder is used to ensure excellent heat dissipation and contribute to lower vehicle weight. A large number of design concepts intended to reduce horsepower loss have been incorpo-

rated throughout the vehicle, including an offset cylinder, roller rocker arm, and a small ACM.

(ii) YZF-R1: This motorcycle features a compact cross-plane-crankshaft engine that was developed to both significantly improve output and reduce weight to achieve victories on the racing circuit. Yamaha's Moto GP-derived racing machine know-how and cutting edge technologies have all been incorporated as much as possible. The maximum output speed and indicated mean effective pressure (IMEP) were both increased, and horsepower loss was reduced in an effort to increase the output. Titanium fracture-split connecting rods were also adopted to help realize a decrease in weight of 1,006 grams compared to the current model.

The rocker-arm valve train features advanced rocker-arm valve actuation to allow for larger valve lift, and the equivalent mass of the structure has been reduced by 20% compared to the conventional lifter structure. The thickness of the crankcase was reduced and engine components are now made from magnesium instead of aluminum to help further reduce weight. The Inertial Measurement Unit (IMU) is an advanced vehicle control technology that uses six axes of measurement. It communicates with the ECU, which activates the technologies in the Yamaha Ride Control (YRC), including ABS, Traction Control System (TCS), Slide Control System (SCS), and Lift Control System (LIF), to significantly increase the level of vehicle control. In addition, the vehicle is equipped with an optional Communication Control Unit (CCU) that can record running data. This data can then be wirelessly downloaded via a smartphone and tablet app, where it can be analyzed by interested riders.

1. 2. 3. Suzuki Motor Corporation

(i) Address 110: This vehicle is equipped with a SEP engine that realizes good fuel efficiency without losing power thanks to improved combustion efficiency and reduced friction loss. Combustion efficiency was increased by calculating and designing the optimal flow of the air-fuel mixture, reducing the weight of the piston, and adopting a roller rocker arm, while fuel efficiency was improved by reducing friction loss within the engine and adopting a high-speed camshaft. These improvements have struck an excellent balance between fuel efficiency and power.

GSX-S1000: This vehicle features an engine designed to win on race day that has been tuned for use on the street, with excellent power and torque characteristics throughout the entire rpm range. The long-stroke engine design with a compact combustion chamber optimizes the compression ratio and makes it possible to adopt flat-top pistons to achieve smooth output characteristics in the pre-rotation region. New pistons, engineered with the use of finite element method (FEM) analysis, were designed and cast to possess the optimal rigidity and weight. New camshaft profiles were designed to optimize valve timing and achieve excellent output characteristics. Suzuki Composite Electrochemical Material (SCEM)-plated cylinders were integrated into the upper crankcase to reduce friction while improving heat transfer, wear resistance, and durability.

1. 2. 4. Kawasaki

(i) Ninja 250 SL ABS: In addition to the strong low- to mid-speed region and pleasant pick-up characteristics, this vehicle also has sharp response in the high-speed region. The weights of the piston, piston pins, and connecting rods were all reduced, thus contributing to better performance characteristics over the entire rpm range. A plated coating has been applied to the inner diameter of the aluminum cylinder to make it sleeveless and reduce weight. Cooling performance was improved through excellent thermal conductivity, and the tight piston and cylinder clearance has provided the vehicle with a high level of power.

(ii) Ninja H2 (overseas model): This vehicle features a supercharger-equipped engine designed and developed completely in-house at Kawasaki for their racing machines which has now been given public road specifications. The result is a highly efficient supercharger that perfectly matches the engine characteristics of the motorcycle. The centrifugal-type supercharger was chosen for its high-rpm performance and is located behind the cylinders. A planetary gear was adopted to drive the impeller in an effort to minimize output loss and reduce the size of the mechanism. The flat-top pistons were cast, rather than forged, an efficient ram air intake was adopted, and the intake chamber is made from aluminum, rather than the more common plastic materials, so that it can withstand the pressure of the supercharger as well as realize excellent chamber stiffness and heat dissipation capabilities. The dog-ring transmission is the same as the one used on the racing version of the vehicle, giving it light operability and short shift times.

Fig. 1 Piaggio MP3 Youban 300

Fig. 2 Yamaha TRICITY 125

Fig. 3 Yamaha MWT-9

2 Trends Outside Japan

2. 1. Trends of each manufacturer

2. 1. 1. BMW Motorrad

R1200 RS: This vehicle is equipped with the traditional horizontally-opposed boxer twin engine and the engine control system has evolved. Now, in addition to the standard Rain and Road engine modes that the rider can switch between, the vehicle is also equipped with Ride Modes Pro, with two more modes: Dynamic and User. The vehicle comes with Dynamic Traction Control (DTC) featuring lean angle sensors for maximum stability while cornering. It is also equipped with Gear Shift Assist Pro, which allows for seamless up- and downshifts without having to use the clutch once the rider is clear of third gear.

2. 2. 2. Ducati

XDiavel: This vehicle has a low-torque L-twin piston engine that generates maximum torque (13.1 kgm) at 5,000 rpm.

Furthermore, Ducati has employed its unique layout of valves with even more narrow included angles called the Testastretta (meaning "narrow head"). The adoption of the Desmodromic Variable Timing (DVT) system smoothly generates a large amount of torque at low engine speeds, and the engine also provides high performance at high engine speeds. The vehicle is also equipped with the Bosch Inertial Measurement Unit (IMU), which dynamically measures pitch and roll angles plus the speed of relative variations in attitude which, when combined with Ducati Traction Control (DTC) and the innovative Ducati Power Launch (DPL), make the XDiavel a technological gem offering high performance and, above all, safety.

3 Research and Development Trends

The Euro 4 emissions standards are now beginning to be introduced in advanced nations, and vehicles compliant with these standards are also being introduced into those markets. At the same time, many manufacturers are no doubt already carrying out research and development work in preparation for the next-generation Euro 5 emissions standards. Engine controls are becoming even more advanced and sophisticated through the application of various new sensors, and it will soon become obligatory to equip vehicles with OBD (vehicle self-diagnostic function) systems. In the motorcycle manufacturing industry the ISO 26262 standard, a generic functional safety standard for electrical and electronic systems, is scheduled to be introduced soon, and the number of companies carrying out research and development of control systems related to functional safety to maintain compliance with this standard is assumed to be increasing. Furthermore, advances in control systems will not only be limited to engine controls. New control systems that will also integrate vehicle body control systems, such as anti-lock braking and electronic suspension are expected to be developed.

The development of components for small engines is now being promoted with an emphasis on the environmental-friendliness of the vehicle. High-efficiency engines are advancing thanks to improvements in basic technologies, such as combustion, and it is assumed that micro hybrid systems, which are now becoming popular in automobiles, will also be developed for motorcycles as well. However, the development of full-fledged hybrid systems for motorcycles seems unlikely due to the physical size, weight, and cost constraints involved. A change to the use of more electrically-powered small engines (motors) is certainly desired from the standpoint of preserving the environment and more economical use of energy, but the key to unlocking this technology is the development of batteries that are relatively low cost and can also provide a sufficient driving range. The major issue facing motorcycle manufacturers is the development of battery technologies with better energy density, safe and stable

operating environments, and lower costs.

The 44th Tokyo Motor Show was held over the course of 11 days starting on October 29, 2015 and attracted some 812,500 visitors. The latest models and concept models from all of the motorcycle manufacturers were on display there, and the following sections will introduce the three main features of motorcycle design observed at this show.

Design Trends

1 Design of Tilting Three-wheeled Models that Lean into Corners

It is said that the birth of two-wheeled vehicles, thanks to the internal combustion engine, occurred sometime between 1870 and 1880, around the time that the telephone was also invented. In the more than 140 years since that time, the telephone has completely evolved in dramatic fashion and the communication infrastructure has also changed massively. However, the same cannot be said of motorcycles and bicycles. Even today, the basic structure of these vehicles, a power source located between the front and rear wheels, has not changed at all.

Of course the human beings that ride on and control motorcycles have not changed significantly either, but in recent years a new form of motorcycle has stepped into the limelight. These are three-wheeled vehicles that take corners by tilting, the same way traditional motorcycles do. Yamaha Motor Co., Ltd. refers to these vehicles with three or more wheels that can lean through corners like motorcycles as Leaning Multi Wheel vehicles LMW. This section will examine the current state of LMW design.

On a three-wheeled leaning vehicle, there are usually two wheels in the front and one wheel in the back that all lean into the turn during cornering so that the vehicle can be ridden with the same feeling as a normal motorcycle or scooter. Piaggio & C SpA of Italy was one of the first manufacturers to try and sell such a vehicle in Europe back in 2006, and they were later imported and sold in Japan as well (Fig. 1). At that time they would have required an ordinary vehicle license to be driven legally in Japan, but the Japanese Road Traffic Law was partially amended in 2009 so that three-wheeled vehicles that satisfied the requirement of having a space of 460 mm or less between the two front wheels would be treated as a motorcycle. Consequently, they can now be driven with the appropriate motorcycle license corresponding to their engine displacement.

In 2014 Yamaha released a LMW called the Tricity 125. The design concept for this vehicle was “smart for all” and it featured a side line that was reminiscent of a single smooth brush stroke with a use of color along this line from front to back that emphasized shadow. The unique two-front wheel style features independent front fenders for both the left and right wheels that narrow down toward the inside. The design is meant to convey a sense of elegance that is more familiar to non-users, and a feeling of modernity and elegance to four-wheel vehicle users (Fig. 2).

At the 2015 Tokyo Motor Show (2015 TMS), the MWT-9 from Yamaha was exhibited as their new concept model for a LMW vehicle that is clearly trying to make the argument that LMW vehicles can be used for sport riding as well.

The design concept for this vehicle was “cornering master”. The dynamic and seamless vehicle body has been fitted with an 850 cc engine. The styling suggests a feeling of maneuverability on winding roads, a feeling of stability at high speeds, and the quick agility needed for driving in town. The modelling of the two front wheels conveys a strong feeling of grip while also providing a strong sense of the underlying cornering performance. The stroke and bank angle of the outside front suspension are advantageous for ensuring the turning angle of the handle bars. All of these functions have been harmonized to help bring to mind the sporty feeling of flying through twisty roads dotted with tight, successive corners and ever-changing road surfaces.

There is an expectation that a vehicle such as this will help to create a new riding sensation based on a sense of stability and security that cannot be realized through a simple extension of the conventional motorcycle design. This form takes on the challenge of developing new modelling by utilizing the fact that there are two front wheels and the leaning movement of the vehicle body during cornering (Fig. 3).

At the Honda booth the sports-hybrid three-wheeled concept model called the Neowing was on exhibit. This vehicle is equipped with a hybrid power unit that com-

Fig. 4 Honda NEOWING

bines a four-cylinder engine with an electric motor.

One of the charms of motorcycles is the visible mechanical greebling, and the Neowing also exudes these mechanical charms to present a strong feeling of advanced technology. This is a dazzling machine, from the cylinder heads, muffler, bevel gears, and shock absorbers, to the tires, brake calipers, and headlights. An original link structure between the two front wheels, and new technology in which an actuator mitigates roll, have both been adopted so that the tilting during cornering can be controlled. Furthermore, the wide tread has made it possible to equip the vehicle with an autonomous function when it is parked.

The seat specifications and position of the handle bars convey a feeling closer to that of a passenger car. The external appearance certainly conveys the organically mechanical feeling of a motorcycle, but when ridden the vehicle definitely provides the comprehensive feeling of a long distance cruiser, so this proposal for a next-generation three-wheeled tilting vehicle is certainly garnering attention (Fig. 4).

The 2015 TMS has revealed that there are currently two main vectors in the design of tilting three-wheel motorcycles. On the one hand are models that leverage the advantages of the tilting movement through comparatively small shifts in vehicle weight while also providing riders with the feelings of stability and safety more associated with an automobile. On the other hand are vehicles that have added this element of greater stability to the exciting feeling of handling a motorcycle, where shifting the vehicle weight back and forth is part of the fun of riding. It can be said that the Honda Neowing represents the first type of vehicle, while the Yamaha MWT-9 represents the second type.

In the future these sorts of three-wheeled tilting motorcycles are expected to evolve further and move beyond the conventional motorcycle forms into a new realm of design.

Fig. 5 Yamaha Passol

Fig. 6 Yamaha EC-02

Fig. 7 EV-Neo, e-Let's, and E-Vino

2 Designs of Electric Models

Next, the trends seen in the designs of electrically-powered motorcycle and scooter models at the 2015 TMS will be examined.

Honda released the first electrically-powered (EV) scooter for practical use back in 1994. It was called the CUV ES and was commercialized and sold in limited quantities to government agencies and local governmental bodies. Over the past 20 plus years since then, both battery and motor control technologies have advanced significantly and today many manufacturers are selling EV motorcycles and scooters as well as announcing new EV motorcycle concept models.

Yamaha is offering EV scooters that reflect its own unique style. The first such EV scooter released as a commercial product by Yamaha was the Passol (class 1 motor-driven cycle) moped in 2002. This vehicle sported a unique, nimble, and slim new design that was only possible because an EV scooter does not need the air intake and exhaust systems required for an internal combustion engine (Fig. 5).

In 2005, Yamaha released the EC-02. The design of the Passol had been focused on convenience and practicality, but the EC-02 placed more emphasis on the hobby side of owning an EV scooter. This vehicle used its playful design and many functions to propose a sense of fun that went beyond just riding the vehicle. The iconic pentagon-shaped aluminum frame in combination with the side panel helped to express the cleanliness, quietness, and quality feel of an EV. The handle bars and other components could be folded away in consideration of possible

storage in a car trunk or even a small apartment. This vehicle really demonstrated the wide-ranging possibilities of EV design (Fig. 6).

In the 2000s the new style of EV scooter that came to the forefront was that of EV commuters. From 2010 onward, the electrification of more and more scooters continued to make steady progress, but the main design point seemed to be a tendency to not outwardly express the fact that the scooter was an EV at all.

In 2010 Honda commercialized their EV-neo scooter aimed at businesses and began leasing them to various corporations. They were also employed as rental scooters at various tourist destinations in Japan. On the side of the vehicle was a motif in the shape of an electrical plug to show that it was an EV, but the basic body design was identical to that of Honda's other business-oriented scooter model, the Benly. The external appearance of the scooter does not strongly emphasize the fact that it is an EV.

There are also other examples of companies downplaying the fact that their scooters are EV. In 2012, Suzuki released an electric scooter (class 1 motor-driven cycle) called the e-Let's. However, the body was based on their Let's 4 Basket scooter, which runs on an internal combustion engine.

The same was true of the E-Vino scooter released by Yamaha in 2015. Its design is exactly the same as their gasoline-engine powered Vino scooter. In all three of these cases the design of the electric scooter was heavily based on the design of a gasoline-engine scooter that was already well known and recognized in the market (Fig. 7).

Consequently, the EV-Cub Concept from Honda displayed as a reference exhibit at the 2015 TMS garnered a lot of attention as the possible next advancement in EV design. The original Super Cub model from Honda has been supported by the fact that its external appearance has barely changed at all from the way of looked 50 years ago. Total worldwide sales of the Super Cub have exceeded 60 million vehicles, making it one of the most used motorcycles in the world. The new EV-Cub Concept has inherited the mantle from the first-generation Super Cub as an "easy-to-ride and economical motorcycle" and is poised to carry on its tradition of being a vehicle for short distance personal commuting.

In other words, the basic concept behind the EV-Cub Concept was that it would inherit the basic characteristics of the first-generation model: good fuel efficiency, practical, reliable, easy-to-ride and maintain, and useful for everyday life. It is a vehicle with excellent environmental performance, in the trusted shape of a commuter bike that customers demand.

The styling of the EV-Cub Concept is characterized by a seamless surface that conveys a sense of gentleness and harkens back to the original model. The pearly white color is intended to convey both a clean image and a strong sense of refinement. The battery has been placed low and near the center of the vehicle body to ensure that it is easy to get on and off the seat, and to help keep the vehicle mass concentrated. The battery can also be removed in consideration of a wide variety of situations (Fig. 8).

Similarly, Yamaha also exhibited two EV concept model motorcycles at the 2015 TMS, the PES2 and the PED2, that should appeal to motorcycle fans. These models do not just present the value of an electric motor power source as a potential solution to environmental issues; but appear to be using the application of EV as a means of realizing motorcycles that are fun to ride as well. The body designs retain the feeling of metal from a conventional motorcycle, but can also be said to emphasize the clean and silent image of electric vehicles.

Both of these models share the same monocoque power unit that also serves as the vehicle frame. In addition, they also share the same color scheme of a white base color with blue accents. This indicates that even though the shapes of these motorcycles are very different, they are both from the same EV genre. The PES2 has two-wheel drive to help ensure efficient transmission of drive force to the road. The PED2, which was referred to as the "EV Serow" by the 2015 TMS attendees, brings to mind the image of quiet trekking, and both of these models shine a light on the possible future of EV design.

Consequently, each manufacturer is working hard to develop their own unique take on the EV motorcycle, but in the future the batteries and even the energy source itself will continue to evolve, and this evolution will have a major influence on the design and modelling of EV motorcycles.

It is fully expected that the future development of new EV models will highlight each company's brand while also offering customers a new lifestyle choice via compact and personal EV transportation with no exhaust emissions or noise.

Fig. 8 EV-Cub Concept, PED2, and PES2

3 Coloring Design that Tells a Story

The only significant surfaces that can usually be painted on motorcycles are the fuel tank, side covers, and fenders. However, in Japan, motorcycles that came with full cowlings as standard equipment started to be sold back around 1980, and some fresh color and graphic designs have emerged since then. According to a recent survey by the Japan Automobile Manufacturers Association (JAMA), approximately 70% of purchasers of on-road vehicle models said that vehicle style and design were a particular point of focus for them when they made their purchase. Obviously, coloring and graphics are two major elements that support the vehicle design. There is not much point in comparing motorcycles to cars when it comes to paint jobs and styling, but the use of various different colors and patterns has also been integrated into the design of motorcycles to enhance their marketability.

All motorcycle manufacturers are aggressively focused on making a dramatic appeal to customers through the use of their corporate colors to enhance the attractiveness of their products. This was clearly visible at the 2015 TMS in the design of the manufacturers' booths and the color schemes on the main models being exhibited. It was all connected to the exciting image of motorcycle racing, and clearly linked to their efforts to build up their brand images.

The Honda booth at the 2015 TMS tried to concentrate all the attention on its flagship model RC213V-S in a tricolor color scheme, as this is the visual identity of Honda motorcycles (Fig. 9).

This tricolor scheme was first used back in 1973 and is intended to replicate the red, blue, and white color scheme of the CB750 racer that competed in the Daytona 200, the largest motorcycle racing event in the U.S. This tricolor color scheme has been used on numerous Honda racing motorcycles over the years in some of the biggest racing events. It was featured on the RCB1000 that debuted in 1976 when it won glory at the European Endurance Championship, the NR500 with elliptical pistons that ran in the World GP in 1979, and the XR500R during its first victory at the 1982 Paris Dakar Rally. Without a doubt this color scheme has come to represent the legends of Honda racing themselves.

Fig. 9 Honda Booth at 2015 Tokyo Motor Show

At the Yamaha booth a largely monotone color scheme that emphasized the color blue was used. The flagship YZF-R1 model displayed front and center also used this same blue as its keynote color. Since 2007 Yamaha has referred to this color as racing blue and has applied it to all of its flagship racing models. There is also a graphic design that combines the company's speed block livery, and this too is used to emphasize the brand image (Fig. 10).

This speed block livery got its start back in the U.S. motorcycle racing scene of the 1970s, but at that time it was black blocks on a yellow and white background. The Yamaha XS-1 used for dirt track racing, the YZR500 that won three world GP500 championships, and the YZM250 super cross bike have all sported this livery. In the 1980s, the block pattern was kept but the color scheme was switched to a red and white base. However, in recent years the blue keynote commercial models and blue keynote sponsor color have proven to be popular, so this racing blue color is now strongly linked to the corporate color.

Lime green is the brand image color for Kawasaki, and their booth at the 2015 TMS featured lime green keynotes over a black base. This color scheme also got its

Fig. 10 Yamaha Booth

Fig. 11 Kawasaki Booth

Fig. 12 Suzuki Booth

Fig. 13 MT-10 and 959 Panigale

start back in 1968 at the Daytona 200. The A1R racer that they used to compete on that day just happened to be lime green. At that time in the racing world, many still believed superstitions and jinxes, and the color green was avoided as it was thought to bring on bad luck. However, Kawasaki dared to choose lime green in an attempt to draw some attention to itself as a challenger of the status quo. After this, the color became more established and was used on Kawasaki motorcycles in GP racing and various other events. In 1980 a lime green Kawasaki Z1 was a part of the battle for the lead during the Suzuka 8 Hours endurance race, indelibly burning this color into the minds of many racing fans. Even now this iconic color scheme is an indispensable part of the Kawasaki motorcycle lineup (Fig. 11).

Although no particularly special color features were seen at the Suzuki booth, a bright yellow color scheme on some products was used to catch the eye. This was intended as homage to the body color of the RH70 that won a world championship back in 1970, and the RM-7 series of commercially-available competition models will also use this color to pay tribute to that legendary machine (Fig. 12).

The Honda tricolor, Yamaha racing blue, Kawasaki lime green, and Suzuki yellow have thus become historical assets and the use of these colors, to help tell the stories of these companies and their products, plays an important role in the current lineup of each manufacturer. These colors have become a characteristic feature of the coloring design of motorcycle products.

Finally, one other trend seen recently in motorcycle design is the use of an accent color. This could be said to be similar to the color coordination method often seen in the world of textile design. A base color is used on the motorcycle body, and the accent color is used on the wheels or other locations. One example of this is the 2016 model of the Ducati super sport bike, the 959 Panigale. The exterior cowling is painted white to help call attention to the balanced body shape that conceals a high-performance engine, and the wheels are a dazzling red. It is meant to evoke the image of an elegant white-tiled room with a single red rose in it.

In a similar fashion, Yamaha applied a pastel yellow color to the wheels of its 2016 model MT-10 Naked R1 superbike. This model reflects much of the technology found on the Yamaha Moto GP machines, but placing this colorful accent to the powerful monotone body near the underbody helps put a little distance between this motorcycle and its full-throttle racing image. Other examples of this kind of color-conscious use of accent colors could be seen on the motorcycles from the other manufacturers as well (Fig. 13).

This concludes the examination of the three main features of motorcycle design observed at the 2015 TMS. There is no doubt that the utilization of the special characteristics of materials and the application of optimized machining and surface treatments will only continue to open up the possibilities for motorcycle design, coloring, and graphics. The future of motorcycle design is going

to advance in step with the progress of technological innovation.

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