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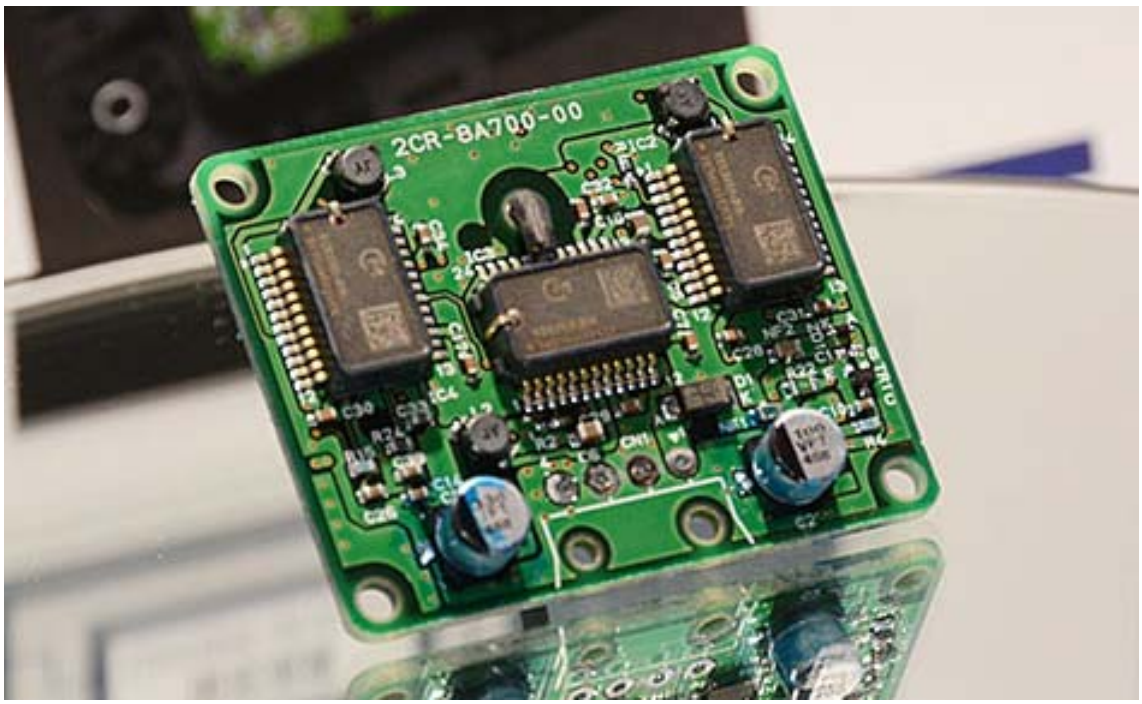

The 6-axis Inertial Measurement Unit (IMU) used on the new YZF-R1

The Core of Yamaha Motor

Core Competency

Part 2: Electronic Control Technology and FRP Processing Technology

Pursuit of added value to strengthen "the unique style of Yamaha"

"The unique style of Yamaha" in our *Monozukuri* is the pursuit of innovative concepts, technology and designs that are in tune with human perceptions. To achieve this kind of *Monozukuri*, Yamaha Motor's two other core competencies—along with our small-engine technology are (1) electronic control technology and (2) FRP processing technology. The first helps us give all of the vehicles and powered products we create comfortable and enjoyable performance that feels natural in all aspects of their handling and operation. The second enables great freedom to shape products and has made it possible for us to come up with innovative designs and styling for our boats, and establish strong new lines of business like our swimming pools. In this issue, we introduce some of the proud Yamaha technology of these two core competencies.

Electronic Control Technology: Bringing Mechanical Power More in Tune with Human Perceptions

Ever since the 1982 release of the XJ750D, Yamaha's first motorcycle with an electronically fuel-injected engine, Yamaha Motor has continued to apply its electronic control technology to products in a wide range of fields. A representative example of this is the "PAS" electrically power assisted bicycle first commercialized and released on the market in 1993.

Pictured is one of Yamaha's drive units for electrically power assisted bicycles for the European market. Cumulative production of these units reached the three million unit mark in April 2015.

Prior to the release of the PAS, other manufacturers were selling bicycles with electric motors, but the motors only added or removed power with a simple On/Off switch. In terms of vehicle classification, they were placed in the same license class as 50cc motorcycles and scooters. Yamaha responded with a completely different concept by developing the Power Assist System (PAS). It used sensors to detect the amount of force applied to the pedals by the rider, and then responded by generating a helpful boost of power in accordance with that pedaling force by means of an electric motor regulated by an electronic control system. The result was a new kind of vehicle that retained the familiar feeling and ease of use of a regular bicycle, but provided a power assist to lighten the rider's work load when pedaling uphill, pedaling into the wind or when carrying loads, etc.

The main point of focus in developing the PAS was to create a control system capable of assisting the effort of the rider while still feeling completely natural and non-intrusive. In order to achieve this goal, the high-speed electronic control system was developed with a top priority on staying in tune with human perceptions. The final system would calculate the optimal proportion of assist force and deliver it through the drive unit. This is an example of the ideals behind Yamaha's electronic control technology.

Electronic Control Technology: Heightened User Friendliness and Enjoyment for a Wider Range of Products

During the 1990s when the PAS was introduced, Yamaha Motor was also releasing production motorcycles featuring Anti-lock Brake Systems (ABS) and Traction Control Systems (TCS). ABS utilizes microcomputers to automatically control brake pressure to help prevent wheels from locking up when braking on road surfaces made slippery by rain or unpaved roads. TCS controls engine rpm in order to prevent excessive sliding of the rear tire. Also at the time, Yamaha was equipping its race machines for the premier 500cc class of the Road Racing World Championship with electronically controlled suspension systems and exploring the possibilities of other types of control technologies to boost performance in the highly competitive race arena. The results of these R&D efforts have been continuously fed back to Yamaha's production models. One the best examples of this is the all-new 2015 YZF-R1 mounting a 6-axis Inertial Measurement Unit (IMU) and five different types of control systems.

Another product category where electronic control technology is an absolute essential for enjoyable riding is EV motorcycles (Electric Vehicles) that run solely on the power of an electric motor. The smooth ride and quietness of the recently released "E-Vino," Yamaha's fourth electric scooter, is the result of the electronic control technology garnered from years of R&D efforts that began in 2002 with the 1st-generation Passol and continued with the EC-02 and EC-03 models. It functions by integrating the brushless DC motor's performance with a drivetrain designed with a low-loss gear system.

Yamaha Motor was also the first to commercialize and market industrial-use unmanned helicopters for use in spreading agrichemicals from the air for crop disease and pest control in agriculture. In order to ensure stable remote-controlled flight from these helicopters, Yamaha developed a variety of electronic control systems, including a flight attitude control system based on a 3-axis gyro sensor system. Today, Yamaha markets unmanned helicopter models with equipment to enable fully autonomous flight. These models have been used successfully for disaster area surveillance, surveying and other uses.

The super-thin power unit of the Passol integrates the brushless DC motor, controller, transmission and a drum brake all into the rear wheel hub.

Yamaha Motor continues to develop and refine its electronic control technology with a paramount ideal: it is human beings that make machines move, so when the performance and the precision with which machines assist the human operator reaches a high level, it is as if the human being and the machine become one. That kind of unity continues to be the goal of our electronic control technology.

FRP Processing Technology: A Quest for Light, Strong and Beautiful Products

It was back in 1958 that fiber reinforced plastic (FRP) drew Yamaha Motor's attention as a new material said to be "stronger than steel and lighter than aluminum." While in the United States for Yamaha's first overseas race, the Catalina GP, president Genichi Kawakami purchased an FRP archery bow. This would be the company's first encounter with the new material.

Ordinary plastics made from petroleum have many advantages, such as being light and highly durable. But they also have the disadvantages of being easily bent and lacking strength as a structural material. FRP is a form of "strengthened plastic" that solves these weak points by taking sheets of hard, strong fibers like fiberglass and mixing in liquid plastics like unsaturated polyester that harden when heated and laying this combination into a mold in numerous layers to solidify into a light and strong composite material.

Yamaha Motor quickly set to work acquiring the manufacturing skills for FRP processing and developing products to use it. In 1961, the company brought to market its first FRP boats: the light and agile RUN-13 and the highly stable CAT-21 with its high-stability catamaran (twin-hull) design. At the same time, Yamaha Motor organized a variety of boating events, such as races, waterskiing, cruising and fishing events that helped spark Japan's first boating boom.

The most basic method for making products with FRP is known as the "hand lay-up" method. The resin gelcoat that will form the outer surface of the product is first applied to the product mold. Then, the repeated process of laying glass fiber cloth into the mold and permeating it with liquid plastic is performed carefully by hand.

Building FRP utility boats in Kenya

Because this method makes it possible to reproduce subtle curves and contours in much the same way as a cast for humans is made by layering on moistened gauze, it allows for a very high level of freedom in the design and shaping of products. Also, the finished surfaces are smooth, beautiful and their hardness makes them resistant to scratches. The process is simple and easy to learn, and it doesn't require sophisticated machining equipment. Other advantages include the fact that small areas of damage to the product

are easily repaired. Taking full advantage of the qualities of FRP, Yamaha expanded its range of boats with numerous different hull types, sizes and designs, from distinctive pleasure-use craft and commercial-use boats for fishery to utility-use boats. The line of Yamaha boats grew to stand alongside the company's outboard motors as a core part of its marine product business.
Since the 1970s, Yamaha Motor has provided technical assistance and instruction in the hand lay-up method as part of the company's efforts to create value for society. These programs have enabled the start of local production of FRP utility boats in markets of Central & South America, Africa and the Middle East, aided in the development of local fishery industry and served to spread the market for these products worldwide.

FRP Processing Technology: Refining the Material's Qualities to Expand Its Uses

Hand lay-up is not the only manufacturing method for FRP. With the industry's progress, development of new methods such as the sheet molding compound (SMC) process and the resin transfer molding (RTM) process have made it possible to create stronger, more beautiful products, and it has also brought greater variation in the types of resin and fiber used.
Yamaha actively introduced these new methods and materials, not only in its growing line of marine products but also in the body parts for our snowmobiles (1968) and golf cars (1975), and in Yamaha's original helmet line (1983). For the newly developed industrial-use unmanned helicopters Yamaha began marketing in 1987, FRP was used for the rotors not only because of the material's lightness and strength but also because it could provide the high precision sought in rotor construction regarding each section's center of gravity, static balance, torsional characteristics and weight balance.
Furthermore, it has been more than 40 years since Yamaha Motor marketed the world's first all-FRP swimming pool in 1974. The company's pool business has sold and installed so many of our revolutionary "unit pools" at schools, nursery schools, public facilities and fitness clubs that their benefits of easy assembly, short installation time and attractive design qualities have made Yamaha the most trusted pool supplier in Japan.
Going forward, FRP will remain a core competency that will continue to support Yamaha business activities in a variety of new fields and products.

Yamaha builds pools in a variety of designs that take advantage of FRP's lightweight, strength/weight ratio, the fact that it doesn't rust and the ease with which it can be shaped.

Message from the Editor

In this issue, we looked at the electronic control technology that enables the smooth, comfortable ride and ease of operation in our vehicles and the FRP processing technology that is used for the body parts of a wide variety of Yamaha vehicles and also to create our swimming pools.
It was also an opportunity to look again at the technologies vital to making products with uniquely Yamaha style. These technologies have grown to feel so natural to us and have blended in so easily with our daily lives and leisure activities that before we knew it, they had become part of our very lifestyle. I think that when products using these technologies can look and feel so natural that we hardly even notice them, that “naturalness” is in fact a good example of true user-friendliness.

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