A scene from attitude testing for the accessory gearbox (AGB), conducted by simulating various attitudes during flight (up/down/left/right). For details, see Special Feature (page 2).

One business in particular at Kawasaki Heavy Industries is gaining momentum—the aircraft gear business. Aspiring to be an excellent company in this sector, Kawasaki offers an impressive array of products, including transmission systems for helicopters, accessory gearboxes, and aircraft power generation systems. In this issue, we bring you a story featuring the core technology behind aircraft gears, for which Kawasaki is known as a vital provider in the aircraft business.

Unrivaled Reliability of Kawasaki Gear Products

The Aerospace Systems Company of Kawasaki has been steadily increasing its gear-related product portfolio. Starting with the development of helicopter transmission systems, it expanded into accessory gearboxes (AGB) that drive auxiliary hydraulic, electric, and air-conditioning equipment, and proprietary traction-drive integrated drive generators (T-IDG™), a power generation system for aircraft. Kawasaki now boasts the industry's most extensive lineup of aircraft gear products.

Most aircraft engine manufacturers work collaboratively with gear manufacturers in developing engine systems. In this regard, Pratt & Whitney has been partnering with Kawasaki in developing advanced systems. In the 1960s, Kawasaki embarked on the development of helicopter transmission systems as part of its larger project to develop helicopters in-house, which later became one of the mainstays of its aircraft business. In a joint development project with Messerschmitt-Bölkow-Blohm (present-day AIRBUS) that began in 1977 for the BK117 helicopter, Kawasaki was tasked with the development of the most critical component—the transmission system. Thanks to its reliability and durability, this system contributed to making the BK117 one of the best-selling helicopters in the world and helped establish the foundation for Kawasaki’s growth in the aircraft business.

A helicopter transmission is installed atop the cabin and performs the following operations: 1) transfers power from the engine to the main rotor (rotor blade) and the tail rotor after stepping down the speed; 2) drives accessories; and 3) transfers the lift generated by the main rotor to the helicopter body, and receives the thrust force as well as the drag force that acts in opposition to the direction of movement.

In the BK117 D-2, the transmission steps down an engine speed of 6,000 rpm to 380 rpm (a reduction ratio of about 16:1), and at the same time increases the torque to 19,600 N·m to drive the main rotor. This is a remarkable torque capacity, sufficient to lift two passenger cars attached to the end of a 1-meter-long bar.

To be more specific, the rotary shafts from a pair of engines that generate a total of 1,000 horsepower are coupled to spiral bevel gears that change the direction of rotary motion by 90 degrees, and simultaneously reduce the engine output rpm. After the directional change, the rotational speed is reduced by a helical gear on the second stage, resulting in an optimal rotor rpm. Other Kawasaki designs use planetary gears to make them more compact, which can achieve a weight-to-horsepower ratio (weight divided by net horsepower) of less than half of an automobile transmission.

Gears Are at the Core of Aircraft Technology

The Aircraft Gear Business at Kawasaki Heavy Industries

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From Machining to Final Inspection: The World’s Top Provider of One-Stop Gear Manufacturing

Achieving lightweight gears demands the utmost effort at thinning without compromising durability. The gears can be as thin as 2 mm, and yet transfer a tremendous amount of power. Gears with lightening holes are inevitably prone to deformation, and yet their tooth shape requires an accuracy at the level of micrometers (µm, which equals 1/1000 millimeter).

Masahiro Gouhashi of the Production Engineering Division comments, “The way gears deform varies, depending on their shape and type of machining process. Therefore, the key to producing accurate gears is minimizing deformation, so that the complex, delicate shapes the designers had first envisioned can be achieved.”

In gear production, the first step is to cut a round gear blank using special machining equipment with a cutter exactly the same shape as the desired teeth. The gear then undergoes a carburizing and quenching process, through which the gear surface absorbs carbon and hardens, followed by a grinding process whereby the teeth are ground to a µm level of precision. The skilful operation of this special equipment is another key expertise required by the manufacturer. Finally, to improve resistance to fatigue, small steel beads are blasted against the surface—a process called “shot peening.”

In the inspection process, none-destructive tests are performed repeatedly. These include “ultrasonic testing,” which uses a special chemical solution to ensure that the strength of the gear has not decreased due to excessive temperature rise during the machining and grinding processes; and “magnetic particle inspection,” which, by magnetizing the gears, detects micro-cracks at the surface that cannot be found in a conventional visual inspection.

Speaking of the comprehensive capabilities Kawasaki exhibits, Gouhashi says, “The most notable feature of our aircraft gear manufacturing is that we are in possession of expertise encompassing the entire process of gear manufacturing—from machining and heat treatment to final inspection—to make sure that no defects in hidden areas go undetected. In the aircraft gear sector, this comprehensive expertise is what gives us a competitive edge in the global arena.”

Outlook Bright on Achieving 60-Minute “LOL (Loss of Lubrication)” Operation

The development divisions experience different challenges in helicopter transmissions than those faced by the manufacturing divisions. This is because the design engineers are tasked not only with improving the precision and performance of individual gears, but also with updating the entire transmission into a high precision, high-performance component of the helicopter, all of which requires a variety of technological innovations. This includes development of bevel gears that can handle faster rotational speeds and greater horsepower, and mechanisms to minimize the vibrations that light, thin gears are prone to generate.

In recent years, demands have been on the rise for improved LOL performance, which is the capability of continuing to fly after loss of lubrication in the transmission. This was originally required for military helicopters, to enable them to reach a safe location in the event they experienced ballistic damage and were faced with a sudden loss of lubricating oil. However, this safety measure is now vital for commercial and emergency helicopters as well, as they often fly in urban areas where landing space may not be readily available. Commercial aircraft are required to have a 30-minute LOL capability, but an even longer operation is called for to ensure the safety of aircraft flying between offshore oil fields and onshore terminals. According to Kenta Ogasawara of the Commercial Engine Project Division, “Improved technology is providing a good outlook for Kawasaki to achieve a 60–70-minute LOL capability, and a demonstration test is planned for the end of fiscal 2018.”

Key to achieving such duration is cooling. A transmission configuration and structure which will preclude the overheating and scoring of gears and bearings is being developed in addition, materials with greater seizure resistance are being selected. At Kawasaki, it is now possible to optimize gear shape and bearing configuration by means of computer simulation, which allows the simulation of temperature changes in transmission gears in the event of LOL. “We hope that this technology will lead to future transmission development with innovative concepts,” adds Ogasawara.
Fan Drive Gear System (FDGS) Is “Heart” of New Engine

At Kawasaki, proactive strategies are being implemented to tap into a promising market involving an FDGS for a geared turbofan (GTF) engine that was developed by Kawasaki’s partner, Pratt & Whitney.

Fans for passenger aircraft turbofan engines have been increasing in size in order to attain higher fuel efficiency. However, due to differences in the rotational speeds of the fans and the turbine, allowing each component to achieve optimal rotational speeds, was deemed challenging. A breakthrough in this stalemate was the GTF engine, which inserts a gearbox between the fan and the turbine, allowing each component to achieve optimal rotational speeds.

In the GTF engine, the FDGS uses planetary gears to make them more compact, lightweight, and the turbine, allowing each component to achieve optimal rotational speeds. The gears can be as thin as 2 mm, and yet transfer a large amount of power with high efficiency.

Kazuhiro Sato, who leads the development project, comments: “With such huge horsepower, even a 1% loss of energy, about 200 hp, will generate 150 kW of heat. This not only compromises the most important factor—fuel efficiency—but also poses serious challenges involving the oil for cooling and the weight and size of heat exchangers.”

This is why, in addition to being lightweight and compact, the FDGS must be designed to minimize losses from gear friction and oil churning. According to Sato, oil and gas mix and flow in a very complex way inside the FDGS, and Kawasaki possesses the world’s most sophisticated technology to computer-simulate this flow. Moreover, the company has developed a proprietary technique that not only optimizes the flow, but also maximizes the lubrication and cooling effects. As a result, an energy efficiency of 99.6% has been achieved.

Kawasaki’s proprietary technologies were all developed in conjunction with the Corporate Technology Division. As a result, an energy efficiency of 99.6% has been achieved.

Fundamentally, gears are used for efficient transfer of energy. The more we try to enhance that efficiency, the more important the role of gears become. They are parts that demonstrate great potential for innovative technologies.

The aircraft gear business at Kawasaki was launched with the licensed production of helicopter transmissions. After that, in conjunction with the Corporate Technology Division, the Aerospace Company tackled various challenges to develop unbreakable, high-performing and reliable products based on proprietary technologies. These advancements are attributable to our integrated manufacturing process, covering all phases from development to manufacturing, and allowing the sharing and solving of problems that arise in between phases. A proactive corporate culture that has encouraged engineers to take on new challenges was another contributor.

As a result, technologies originally associated with helicopter transmissions have evolved to a level that is now applicable to the accessory gearboxes that drive auxiliary equipment, the traction-drive integrated drive generator (T-IDG™) that is driven by the aircraft engine to generate electrical power, and now, future technology—the FDGS. These technologies are indispensable to the operation of aircraft, and, considering the future growth of the aviation industry and the expansion of gear applications (“gearification”), our gear business has great potential for growth and is expected to become one of the pillars of the Aerospace Company.

In the aircraft sector, continuous efforts are being made to reduce fuel consumption and emissions, and eventually there will come a time when more advanced GTFs, open rotor engines, and other next generation engines are the only options. Even when such trends become prevalent, gears will still be pivotal parts. Without gears, there would be no next-generation engines.

The drivers of new aircraft industry trends are prominent U.S. and European manufacturers. However, in terms of gear technology that can turn these trends into reality, or which serves as the backbone of innovation and demonstrates great potential in creating technological breakthroughs, Kawasaki is the world leader. In my opinion, it is not an overstatement to say that Kawasaki’s technological innovations drive forward the new trends. Indeed, those who rule the gears, rule the world.

**“Gearification” is a term coined to mean “using gears to drive technologies.”**