

Development of Payload Fairings for Launch Vehicle



It is expected that launches of satellites will continue to increase in the future across the world including emerging and developing countries due to the benefits of images and positional information acquired by satellites. The fairing is a component that protects satellites on the top of the launch vehicle. This component plays an important role in the satellite launch business because the temperature and acoustic vibration environment around the satellite is critical along with the launch cost and the orbit injection accuracy.

Kawasaki has successfully produced a large fairing for the H-II Launch Vehicle for the first time in Japan. Since then, we have made technical improvements on an ongoing basis to continue supplying high-performance fairings at a low cost.

Introduction

National security, disaster prevention and private services that use images and positional information acquired by satellites have become common, and the space industry market is expanding. On the other hand, the entry of American entrepreneurs into the satellite launch business is exerting downward pressure on prices. This is leading to the need to supply high-performance launch vehicles at lower prices.

1 Background

There are two types of satellites. One is government satellites as represented by reconnaissance and weather satellites; the other is commercial satellites as represented by communications and broadcasting satellites. In the satellite launch business, aerospace companies from Japan, the US, Europe and Russia have continued to compete against one other for 20 to 30 commercial satellites a year. In 2010, however, as Space Exploration Technologies Corp. (SpaceX) made inroads into this business with its low-priced Falcon 9 launch vehicle, prices plunged. Moreover, the progress of launch vehicle technology from emerging countries such as China and India is remarkable, and competition is expected to further intensify in the future. Consequently, Japan, the US and Europe are now promoting development of next-generation, cost-competitive large launch vehicles, and

plan to put them on the market in about 2020.

Since developing the payload fairing for the H-II Launch Vehicle in 1984, Kawasaki has continued to improve its technology through the H-IIA/H-IIB Launch Vehicles and the Epsilon Launch Vehicle¹⁾, and now supplies payload fairings for all of Japan's major launch vehicles. At present, Kawasaki is in charge of developing the payload fairing for the H3 Launch Vehicle, and is engaged in developing of high-performance payload fairings at low cost with the aim of launching the first vehicle in fiscal 2020.

2 Payload fairing

As **Fig. 1** shows, a payload fairing keeps the internal temperature/humidity and cleanliness (in the space where a satellite is mounted) constant until the launch vehicle lifts off, and reduces aerodynamic drag during the flight. At the same time it helps to protect the satellite from aerodynamic heating and acoustic vibration. Once the launch vehicle reaches an altitude of about 100 km, where the atmosphere is sufficiently rarefied, the payload fairing splits into two pieces by actuating its separation system, rotates on a hinge and separates from the launch vehicle.

Figure 2 shows the structure of payload fairing. It has two half-shell bodies that are joined together by the separation system (vertical separation system) in the axial direction, and they are joined to the body of the launch vehicle by the separation system (horizontal separation system) in the circumference direction. The payload fairing

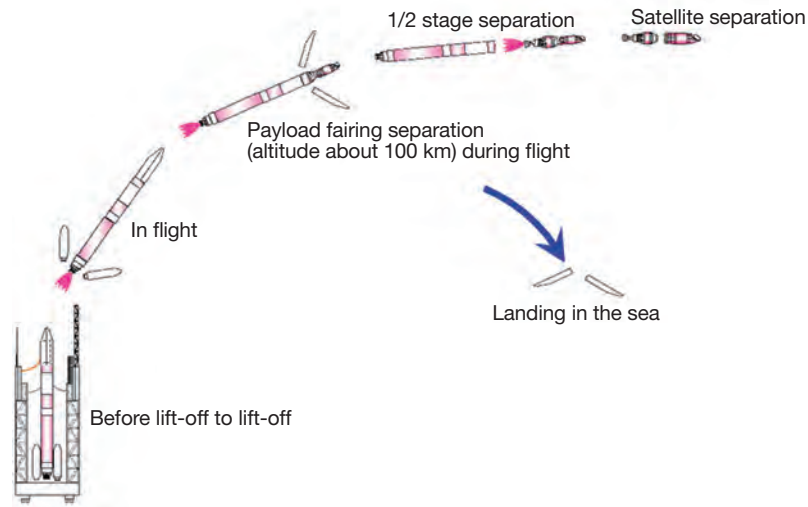


Fig. 1 Launch sequence

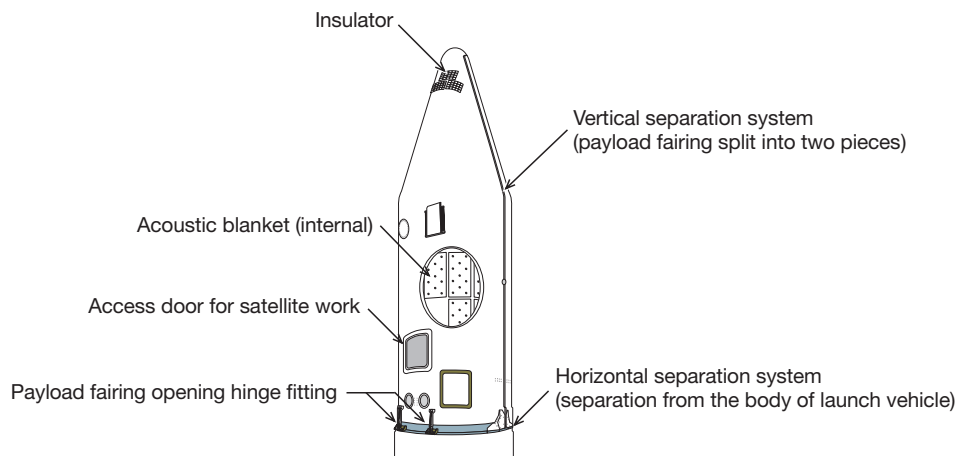


Fig. 2 Configuration of payload fairing

has an access door used by satellite crew for maintenance and a radio transparent window for communication between satellites and their launch facilities. Moreover, the payload fairing has an air-conditioning door draw in clean air into the inside at the launch facility, insulators to prevent the body structure and interior from heating up due to aerodynamic heating, and an acoustic blanket as sound-absorbing material to reduce acoustic vibration caused by engines and the atmosphere.

To minimize the weight of the satellite, which has many delicate electronic components aboard, it is important to ease the environmental conditions around the satellite such as heat, acoustic vibration and shock. This is the role payload fairings play.

3 Technology to support payload fairings

(1) Separation systems

Separation systems are the most technically difficult components of payload fairings to design and make. As separation systems are strength members that connect structures, they must be strong enough to endure the aerodynamic loads generated at supersonic speeds. Yet the strength needs to be low enough to separate payload fairings with minimal energy to reduce the shock to satellites during separation. This means payload fairings must be designed to bring such mutually contradictory requirements into balance. As faulty payload fairing

separation directly leads to mission failure, high reliability is critical.

Kawasaki has decided to develop Japan's unique separation system based on the frangible bolt (notched bolt) method. This method was used in a canopy emergency separation system for fighter aircraft at the time when development of the payload fairing for the H-II Launch Vehicle was underway. Priority was given to higher reliability and lower cost. This method employs explosive force to cut a bolt that features a V-shaped groove (notch) for easier cutting. Although development took a long time, as even slight changes in parameters of materials, notch shapes and plate thickness of stainless steel oval tube cause bolt uncut or oval tube ruptures that lead to faulty separation and satellite contamination, the great number of tests have resulted in highly reliable separation systems that can be applied new types of fairings even today (Fig. 3).

(2) Environmental mitigation

(i) Insulators

To prevent rises in temperature of body structures due to the heat caused by the friction against the atmosphere, and maintain appropriate temperatures around satellites, insulators are applied to the outer surfaces of payload fairings. Kawasaki developed a light-weight insulator for the payload fairing of the H-II Launch Vehicle by mixing glass microballoons into silicone resin, and achieved both weight reduction and heat insulation improvement at the same time.

(ii) Acoustic blanket

To reduce acoustic vibration caused by engines and friction against the atmosphere, acoustic blankets are applied to the inner surfaces of payload fairings. Glass wool and resin foam are used for this insulator, and the insulating material is packed in filter-equipped covers to

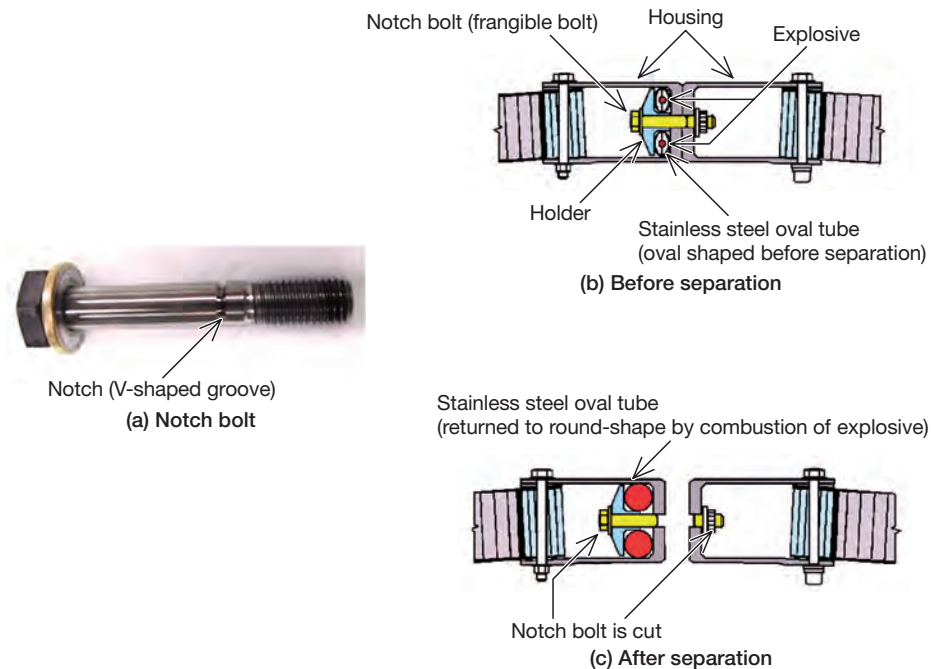


Fig. 3 Separation mechanism of payload fairing from Kawasaki

prevent dust from escaping into the satellite compartment. The aim is to prevent the covers from rupturing in decompressed environment as the launch vehicle climbs. This means decompression, in addition to weight minimization, is also an important factor in designing launch-vehicle equipment.

(3) Structure and shape

(i) Structure

Conventional payload fairings have a lightweight and highly bending stiffness honeycomb sandwich structure that can reduce deformation at the time of opening as much as possible and reduce aerodynamic drag, ensuring more space to carry satellites within a smaller diameter.

The sandwich structure joins thin plates to both sides of a lightweight core material. The advantage of this structure is that increasing the core thickness makes it very difficult for the sandwich structure to deform while minimizing any weight increase. A structure that uses a honeycomb core for its core material is called a honeycomb sandwich structure. Honeycomb core materials include aluminum alloys and meta-aramid fibers. And as for skin materials, aluminum alloys and carbon fiber reinforced plastics (CFRP) are often used.

Kawasaki's payload fairings usually use aluminum alloy-honeycomb/aluminum-alloy skin structures, but CFRP skins are also used for lower payload fairings that require weight reduction in some cases.

(ii) Shape

The H-II is a four-meter-diameter launch vehicle capable of launching a four-ton satellite into geostationary transfer orbit (GTO). The masses and shapes of satellites vary from mission to mission, and these include payloads such as four-meter or larger diameter mega-satellites and two-ton or less small satellites. As **Fig. 4** shows, therefore, to increase the usefulness of launch vehicles, a five-meter-diameter payload fairing (5S) for mega-satellites

and payload fairings (4/4D-LS, 5/4D) capable of carrying two satellites at the same time were developed.

To cope with the increased variations of fairings, many different molds are needed to shape the payload fairings, and many assembly jigs and tools are required. However, to reduce non-recurring costs as much as possible, we have achieved commonality of panels among respective types of payload fairings, and jigs and tools include length-adjusting functions and other ideas.

4 Approaches to new technology

(1) Approaches to the Epsilon Launch Vehicle

The development of payload fairings for the Epsilon Launch Vehicle started in 2010. For this project, Kawasaki addressed new technology development by following the designs of the H-II series such as H-IIA/H-IIB with the aim of reducing costs and improving convenience.

(i) Half-shell integrally submerging body structure

Payload fairings that separate from launch vehicles and land in the sea do not submerge but float because of the hollows in their honeycomb structure. In Japan, to avoid floating payload fairings from hindering the navigation of ships, they are recovered by ships after lift-off. However, as the cost of recovery is high and recovery depends on the weathers, payload fairings are now required to submerge.

Therefore, the sound-absorbing honeycomb cores of aircraft engine nacelles are now applied. These honeycomb cores are added with slots on cell walls as shown in **Fig. 5** to drain rainfall water and cleaning water. When applied to the payload fairings, this structure allows sea water to enter the panels and sink them.

In the H-II series, two or more panels are joined together by bolts to make a half-shell body structure. In the case of the payload fairing for the Epsilon Launch Vehicle, the assembly cost was reduced as the half-shell integral molding was made possible by the slightly curved surface shape of the joint between the top cone and cylinder body.

As for the half-shell integral molding, these was a manufacturing problem where it was difficult to access the top of the half-shell panel when laminating the components such as skins, cores and adhesives. We solved the problem by creating appropriate shaping dies and scaffolding after repeated simulations that used three-dimensional CAD at the time of designing the jigs and tools.

(ii) Sheet-pasting type insulator

In the case of payload fairings for the H-II series, the aforementioned silicone insulator containing glass microballoons was spray-coated in the dedicated coating booth. However, as it took a long time to dry the insulator,

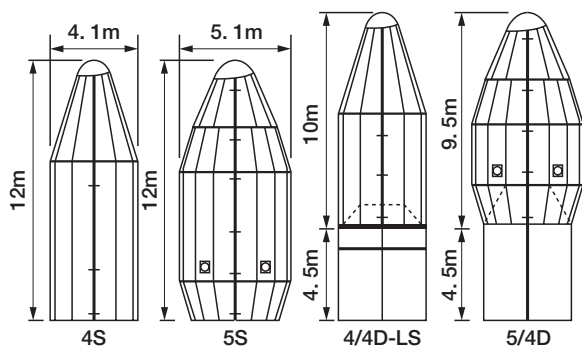


Fig. 4 Forms of payload fairings

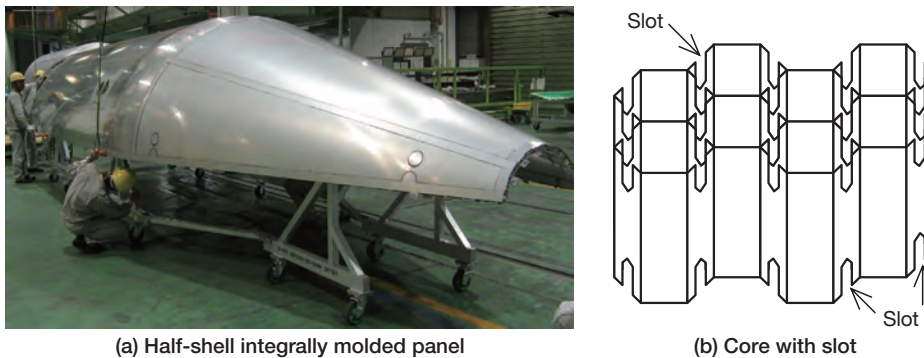


Fig. 5 Structure of the Epsilon's payload fairing

the coating step constrained production in some cases in proportion to the increase in the number of payload fairings to be produced. We developed a new method to paste sheet-shaped silicone foams with adhesives. This method made it possible to insulate payload fairings in the assembly area, removing that constraint.

(iii) Quick-access door

As the Epsilon Launch Vehicle uses solid propellants, it is unnecessary to take much time to fuel it immediately before lift-off, unlike liquid-propellant rockets. To capitalize on this lift-off readiness to the greatest extent, an invention was required to shorten the maintenance time of launch vehicles and satellites by shortening the time to close access doors of payload fairings.

(2) Approaches for the H3 Launch Vehicle

As mentioned at the beginning, future launch vehicles will need to be cost competitive. The H3 Launch Vehicle is aimed at providing high reliability and flexible services appropriate to satellite missions at low cost. We are taking the following approaches when it comes to payload fairing development:

(i) Introduction of Automated Fiber Placement (AFP)

To simultaneously cope with the reduction in production cost of body structure panels and increase in the number of payload fairings to be produced, Automated Fiber Placement (AFP) will be introduced, and CFRP will be installed at low cost.

AFP is applied to the production of Boeing 787 fuselages and is also being widely introduced in the US and Europe. However, new technology will be required for placing it on honeycombs. For example, it will be

necessary to fix honeycomb cores in dies and apply appropriate tension to prevent CFRP to hanging over between cell walls.

(ii) Using Out of Autoclave adhesive technology

In the case of payload fairings for the H-IIA/H-IIB Launch Vehicles, body structure panels are joined together by nuts and bolts. The H3 Launch Vehicle, however, uses Out of Autoclave adhesive technology to simultaneously reduce the mass and cost by employing adhesive technology to the greatest extent possible.

Compared with autoclave molding that is performed at five to six times atmospheric pressure, as components are pressed and bonded at vacuum pressure, if degassing before heating is not sufficient, voids are formed in adhesives, reducing their strength. Therefore, we needed to modify the jigs and tools after repeated coupon tests to create production conditions that sufficiently reduce voids. Preparations are underway toward producing actual payload fairings by bonding curved panels that simulate the top of the payload fairing, as **Fig. 6** shows.

(iii) Demonstration of synergetic effects between different types

In addition to the technologies outlines above, we plan to improve those technologies acquired through the Epsilon Launch Vehicle project, such as the submerging structure, the quick-access door and sheet-type insulator, and apply them to our payload fairings. There are also plans to develop a new version of the Epsilon Launch Vehicle. In the future, we see opportunities for efficiently evolving our payload fairing technology by applying the synergy existing between different types of launch vehicles such as the H3 and the Epsilon.

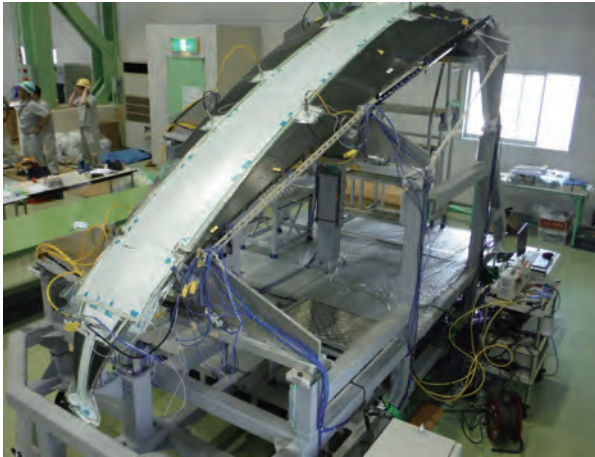


Fig. 6 Out of Autoclave joining of curved panels

Conclusion

In the future, emerging countries are expected to make inroads into the satellite launch business, and cost competitiveness will be more important than ever before. We aim to maintain our international competitiveness by bringing together our in-house technologies and continuing to develop and expand our payload fairing business into the future.

Reference

- 1) Komada, Horie, Tsutsui, Sekine, Kobayashi, Hirano, Koda, Sato, Onikura, Fukuno, Tagawa, Toyoda: "H-IIB launch vehicle fairing for space station transfer vehicles (HTV)," Kawasaki Technical Review No. 171, pp. 20-23 (2011)



Naruhiko Chiku

Space Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company



Yoshihiko Komada

Space Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company



Seiji Nishio

Defense and Aerospace Business Department,
Defense and Aerospace Project Division,
Aerospace Systems Company



Makoto Tsutsui

Space Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company



Makoto Hiyoshi

Space Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company



Masakazu Kobayashi

Space Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company



Atsushi Hirano

Space Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company



Kenichi Koda

Space Systems Engineering Department,
Defense and Aerospace Project Division,
Aerospace Systems Company