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Safety design of compressed hydrogen trailers with composite cylinders

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ABSTRACT

Compressed hydrogen is delivered by trailers in steel cylinders at 19.6 MPa in Japan. Kawasaki Heavy Industries, Ltd. developed two compressed hydrogen trailers with composite cylinders in collaboration with JX Nippon Oil in a project of the New Energy and Industrial Technology Development Organization (NEDO).

The first trailer, which was the first hydrogen trailer with composite cylinder in Japan, has 35 MPa cylinders and the second trailer has 45 MPa cylinders. These trailers have been operated transporting hydrogen and feedstock to hydrogen refueling stations without the accident. This paper describes the safety design, including compliance with regulations, the influence of vibrations, and safety verification in case of a collision.

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Introduction

In Japan, a total of 13 companies, automobile manufacturers and hydrogen providers agreed to make joint efforts to introduce fuel cell vehicles (FCVs) into the domestic market, start the spread of hydrogen infrastructure. According to their joint announcement, the automobile manufacturers aim to sell FCV production cars, while the energy companies aim to antecedently establish about 100 hydrogen stations mainly in four metropolitan areas of Japan by 2015 [1].

To achieve commercial spread of FCVs, it is necessary not only to improve the durability and reliability of the vehicle itself and hydrogen stations, and make efforts to reduce costs, but also to do experiments in order to validate standards, and verify the business feasibility of planned

commercialization. For this purpose, the New Energy and Industrial Technology Development Organization (NEDO) is promoting various types of research and development of hydrogen infrastructure and supply systems. In particular, NEDO is promoting research into the deregulation of 10 items concerning hydrogen infrastructure under the “Regulation Reviews concerning Construction and Operation of Hydrogen Stations” project. In addition, under the “Technical and Social Demonstration of Regional Hydrogen Supply Infrastructure” project, NEDO obtained data from a demonstration experiment of a hydrogen station under conditions close to the actual use of the station. Based on the data, it is possible to verify and assess energy efficiency of the hydrogen station and the hydrogen supply cost, and studying practical solutions to issues for the practical utilization of hydrogen supply infrastructure, etc.

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Table 1 – Specifications of 35 MPa high-pressure hydrogen trailer.

35 MPa high-pressure hydrogen trailer		Composites cylinders	
Length	9560 mm	Length	2030 mm
Width	2490 mm	Diameter	416 mm
Height	3230 mm	Weight	101 kg
Weight	11,130 kg	Pressure	35 MPa
Number of cylinders	20	Water volume capacity	205 L
Cylinder weight	110 kg	Composites type	Type3

Among these R&D items, Kawasaki Heavy Industries has developed the first high-pressure hydrogen trailer to contain composite cylinders in Japan. This trailer transports to hydrogen stations high-pressure hydrogen produced in a hydrogen manufacturing plant, in order to supply the hydrogen to FCVs. Up to now, high-pressure hydrogen has been conventionally carried by a 19.6 MPa trailer with steel cylinders that contain about 200 kg of hydrogen. The trailer cannot load more than 200 kg of hydrogen due to the fact that the steel cylinders that are heavy. Our new trailer uses composite cylinders that can increase the pressure of hydrogen to transport while also reducing weight. Consequently, the trailer will be able to load hydrogen of 400 kg or more in the future. This paper outlines our new trailer and reports legal measures for the safety of this trailer. In addition, it presents the details of Kawasaki Heavy Industries' independent review of trailer collisions and vibrations.

System for development of high-pressure hydrogen trailer

Both 35 and 45 MPa high-pressure hydrogen trailers were developed respectively under the “Regulation Reviews concerning Construction and Operation of Hydrogen Stations” and “Technical and Social Demonstration of Regional Hydrogen Supply Infrastructure” projects.

As a member of the Research Association of Hydrogen Supply/Utilization Technology (HySUT), Kawasaki Heavy Industries took charge of the development of the relevant trailer, while JX Nippon Oil & Energy Corporation was charged with the operation of the trailer.

Table 2 – Specifications of 45 MPa high-pressure hydrogen trailer.

45 MPa high-pressure hydrogen trailer		Composite cylinders	
Length	10,260 mm	Length	3025 mm
Width	2490 mm	Diameter	436 mm
Height	3360 mm	Weight	220 kg
Weight	17,150 kg	Pressure	45 MPa
Number of cylinders	24	Water volume capacity	300 L
Cylinder weight	260 kg	Composites type	Type3

Positioning and general specifications of the developed trailer

35 MPa high-pressure hydrogen trailer

The 35 MPa high-pressure hydrogen trailer is the first high-pressure hydrogen trailer in Japan that contains composite cylinders. The specifications and a photograph of the trailer are shown in Table 1 and in Fig. 1, respectively. The standard for composite cylinders and accessories on a Japanese compressed hydrogen transportation vehicle was employed for the 35 MP cylinders, according to the JIGA-T-S/12/04 [2] and JIGA-T-S/13/04 [3]. The total load for a single trailer was determined according to the minimum requirements in the regulation reviews project.

45 MPa high-pressure hydrogen trailer

As a part of a transport model for the first future hydrogen station in Japan, the 45 MP high-pressure hydrogen trailer is filled with hydrogen at a hydrogen delivery facility, transports the high-pressure hydrogen, stores it in an off-site hydrogen station, and supplies the hydrogen to other hydrogen stations. The specifications and the appearance of the trailer are shown in Table 2 and in Fig. 2, respectively. For the pressure specifications, the pressure during commercial transport by cylinder in Japan is set at 45 MPa. Consequently, 45 MPa was employed for the 45 MPa cylinders. The total load for a single trailer was determined based on the required minimum amount of hydrogen in the social demonstration project.



(a) Appearance of 35 MPa trailer



(b) Appearance of composite cylinders

Fig. 1 – Appearance of 35 MPa high-pressure hydrogen trailer.

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