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Kawasaki's technology to establish hydrogen supply chain

Luis Quadrante, Technical manager, Kawasaki Heavy industries (U.K.) Ltd.
Tomohiro Katayama, Assistant manager, Kawasaki Heavy Industries Ltd.
Rikako Aramaki, Naval architect, Kawasaki Heavy Industries Ltd.

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1. Introduction

People in the wold are living in a period in which much is being discussed and done towards energy transition.

There are two main reasons behind it:

- The first and openly discussed is around the negative environmental effects that the excessive emission of GHG gases are causing and the acknowledgment that de-carbonization of the world's energy matrix is necessary.

- The second is energy security. The instability of the geopolitical situation around the world clearly showed us that the high level of dependence of oil and gas as energy sources is prejudicial to the world's economy and that the diversification of energy sources is necessary.

With that in mind we can see that there are various projects in course around the world to produce electricity from underutilized sources and renewable sources. Among them we can highlight the brown coal in Australia, hydropower, solar and wind.

However, there is still a challenge to overcome. The regions with high potential for electricity production are not evenly distributed around the world. As consequence, there will be areas with surplus of electricity due to its high potential for generation, but electricity cannot be simply stored and transported in its pure nature. Therefore, the electricity must be transformed in something that can be transported.

One of the best options is to generate hydrogen using the surplus this surplus of electricity and then transport it to countries that have a deficit in energy

production. There are several ongoing discussions and parallel developments around the best solution for long distance transportation of hydrogen.

In this scenario, we, Kawasaki Heavy Industries (KHI), are focusing on liquefied hydrogen, which enables large amount, long distance transportation and long term storage of an energy source.

2. Outline of hydrogen supply chain

The concept of a CO2 free hydrogen supply chain which was announced in 2010 in Japan. The objective is to establish stable supply of hydrogen while suppressing CO2 emission in the process of Production, Transportation, Storage and utilization throughout the entire supply chain as shown in figure 1.

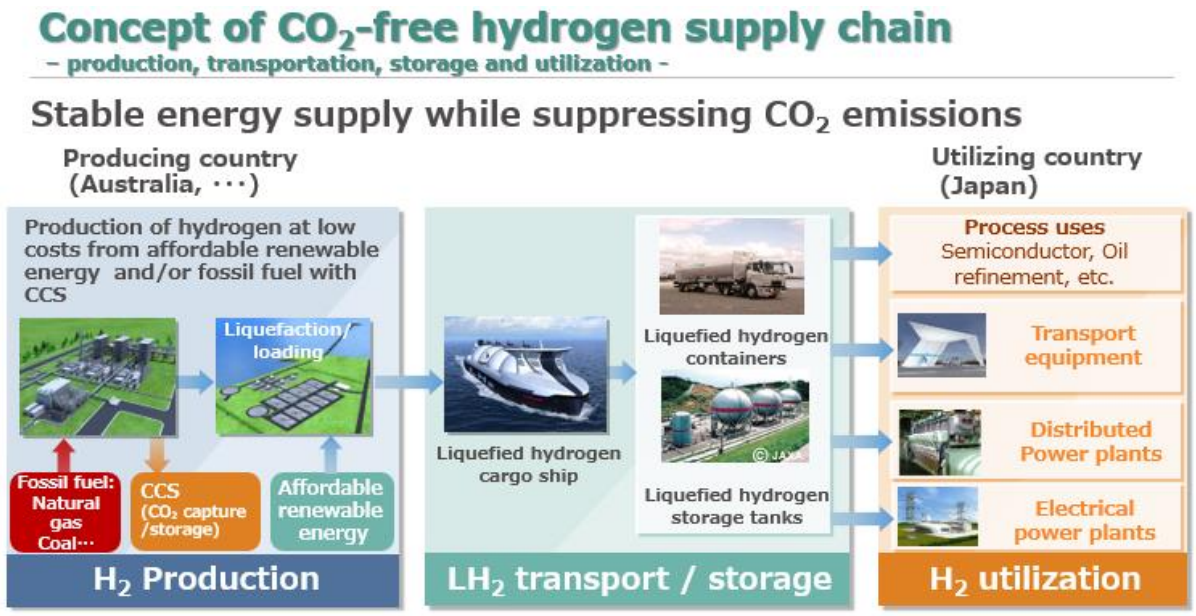

Figure 1: outline of hydrogen supply chain

Hydrogen is to be produced using renewable energy sources and also from fossil fuels paired with Carbon Capture and Storage systems (CCS), in which all the CO2 emitted is captured and stored underground.

Then the produced hydrogen is to be transported to Japan by liquefied hydrogen carriers to finally reach the final consumers which includes power plants, transport and industry.

3. Demonstration by pilot project – Cargo handling system

KHI completed the development, design and construction of a world's first liquefied hydrogen carrier "Suiso Frontier" which was put into service in 2021.

"Suiso Frontier" is provided with a new developed cargo containment system with a high-performance vacuum insulation technology. The vacuum insulation system adopted for this ship is a core technology that enables long-term and long-distance international transport of liquefied hydrogen. KHI has established the design, manufacturing and quality control to maintain the vacuum and ensure its performance for a long time, and succeeded in putting it into service. In addition, KHI succeeded in demonstrating insulation performance and reliability through a gas trial and cargo full loading test using liquefied hydrogen during several months before ship's delivery.

Liquefied hydrogen has significantly different characteristics such as temperature, density, and diffusivity compared to conventional cargo such as LNG and LPG handled by ships. Therefore, cargo handling systems with high safety and reliability were required. At gas trial, cargo handling systems such as newly developed cargo pumps, cargo compressors, cargo heat exchangers, instrumentation such as liquefied hydrogen level gauges, gas combustion units,

and vacuum insulated double wall pipes has been demonstrated. KHI carried out the verification of the cargo handling systems by conducting operation using liquefied hydrogen for each equipment and machineries to confirm its performance and reliability.

Furthermore, in order to realize safe liquefied hydrogen loading and unloading for ship operator, it is essential not only to verify the reliability of equipment and machineries, but also to establish safe operation procedure. Prior to carrying out the world's first liquefied hydrogen loading and unloading operation, safety verification was conducted from multiple perspectives, and a safe loading and unloading procedure was successfully established.

These several months of gas trial and cargo full loading test provided sufficient data for analysis and confirmation of the reliability of both the cargo containment system and cargo handling system. Through these trials and tests, KHI has collected valuable data and established technology for transporting liquefied hydrogen safely, in large quantities, and more efficiently.

4. Establishment of commercial scale hydrogen supply chain

Based on the technology proven by "Suiso Frontier", KHI continues to develop technology to realize scale-up of international transportation of liquefied hydrogen backed by the demonstration results.

Japanese government expressed their new hydrogen strategy in 2023, in which the amount of hydrogen used in Japan will be gradually increased from 3 million tons per year in 2030 to 20 million tons in 2050 and its unit price will reduce from 30 JPY per Nm3 to 20 JPY per Nm3, respectively. Reduction of costs will make possible the expansion of the use of hydrogen and the establishment of a hydrogen society in Japan.

Based on this background, KHI are newly developing 160,000m3 type liquefied hydrogen carrier, as shown in figure 2, to contribute an establishment of hydrogen society in Japan.

Figure 2: 160,000m3 type LH2 carrier

To complete a development of large ship, core systems such as cargo containments system, cargo handling system and hydrogen fuelled propulsion system need to be innovated to suitable ones for large ship. For this purpose, KHI developed core novel technologies, which are a novel cargo containment system, hydrogen fuelled boiler and hydrogen fuelled dual fuel engine.

In addition, to ensure safety of the large ship, KHI collaborated with ClassNK to conduct comprehensive risk assessment of all core systems and large ship itself. As the result, KHI obtained approval in principle (AiP) for the 160,000m3 type LH2 carrier from ClassNK in 2022. KHI will be able to utilize these novel technologies to various size of ships and to propose various ships in accordance with market needs.

5. Conclusion

Hydrogen can be produced around the world from a wide range of energy sources. The liquefied hydrogen carrier is one of key components to establish the supply chain, because it can transport a large amount of hydrogen efficiently. KHI completely demonstrated long-distance marine transportation of liquefied hydrogen by world's first ship "SUISO Frontier".

For commercialization, scale up of the ship is essential to reduce hydrogen cost. Wide range of technologies to achieve scale up of the ship will be available soon. And finally, KHI can provide various size of liquefied hydrogen carriers, from small size to large size, in accordance with market needs. KHI will use its own advanced technology to contribute to a carbon neutral society.