Bölüm 3

A Review on The Use of Nuclear Energy in Cruises

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Abstract

Aim

it is crucial to use available resources correctly and consistently while producing and consuming energy. This study examines the possible benefits of using nuclear energy in cruise ships, which require high energy due to their large scale and numbers of guests.

Method

The study is a review prepared by conducting literature research.

Findings

Since nuclear energy produces more power than water, hydrogen, solar, and wind energy generation systems and produces almost zero carbon dioxide emissions, it has the capacity to fill the gap caused by the depletion of fossil fuels. Besides clean and renewable energies, the use of nuclear energy and power generation is inevitable.

Results and Suggestions

The use of nuclear energy in such ships could provide important opportunities, primarily because it offers long-distance navigation and easy storage.

Originality

Making use of nuclear energy in the determination of sustainable tourism goals should be priority in the development plans of all nations.

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1. Introduction

Most developed countries have grown economically and socially in the last two decades thanks to tourism (MacNeill & Wozniak, 2018). Cruise ship tourism, which is within the scope of marine tourism, is the fastest-growing segment of this industry. The word *cruise* denotes traveling, wandering, watching (shipping), and sea cruising, among other meanings (Dictionary of Maritime Terms, 2020). *Cruise* is used here in reference to cruise tourism for vacation purposes, accommodation, certain standards of size and comfort, resting in a "floating hotel," and making international visits (Dilek et al., 2015). A cruise ship evokes the image of a "wandering island" and contains many activities found in large cities. With their many room options, recreation areas, and restaurants where you can experience the flavours of different countries, cruise ships are priority holiday options among many age groups (Zheng et al., 2019). As the size and passenger capacities of cruise ships increase, the recreational activities offered also diversify.

In the beginning, travel by ship was accepted as a preferred way of life for the elite. After the Second World War, the decrease in the number of such cruises and the increase in passenger planes caused a loss of commercial value in ships. However, the middle of the 20th century brought about a tremendous revival. Since the beginning of 1990, the sector has continued to increase disproportionately in developing countries (MacNeill & Wozniak, 2018). Considering its share of international growth, cruise tourism can be seen as a sub-sector of sustainable tourism. Cruise ship operating companies have broadened their target audiences to appeal by turning to different markets and recreations. Given that people of all ages, from children to the elderly, may patronize cruise ships, different options and times, high-quality service offerings, prices, and routes have been provided to attract these guests. As a result, there has been an annual tourism growth of 8% globally: cruise tourism hosted 8.5 million passengers between 1980 and 1997 (Wood, 2000) alone. From 2003 to 2014, worldwide cruise demand increased from 12 million passengers to 21.6 million passengers across 410 cruise lines. The total revenues of the ships have exceeded 37.1 billion dollars (Sun et al., 2011; Clia, 2014). European tourists played an active role in cruise tourism in 2013, when 30% of the total passengers consisted of Europeans, and 31.2 million tourists visited 250 port cities via cruise lines on routes that include stopovers throughout Europe and the Baltic Sea. The result was a trade economy consisting of 16 billion dollars of direct expenditure within the scope of cruise tourism (CLIA, 2014). The Mediterranean and

European fleets consist of 166 large and small cruise ships serving a total of 3.86 million passengers (Paoli et al., 2017).

2. Literature Review

2.1. Nuclear Energy

Energy needs and consumption are at the forefront of national development in many countries. Because energy and industrial products are the most important and vital gains of production, it is imperative to supply the energy needed by the people and the economy in a continuous, timely, reliable, cheap, and clean way and to produce alternative energy sources to meet increasing demands (Pamir, 2012). While there have been positive developments in the field of physics and chemistry for several centuries, our examination of the structure of the atomic nucleus is only one century old. Following Crookes's ionization of gas with an electric discharge in 1879, electronics were identified as the source of electricity in 1897, and penetrating X-rays were discovered in 1895, as were gamma rays in 1896. The determination of the properties of the radioactive element by Curie in 1898 accelerated the developments related to energy. Along with this, energy security problems also arose. Breit and Wigner provided the theoretical explanation of slow neutron processes in 1936. Measuring the distribution of fast and thermal neutrons and explaining the behaviour in terms of elastic scattering, chemical bonding effects, and thermal motion in target molecules, the existence of nuclear energy was revealed (Murray & Holbert, 2019).

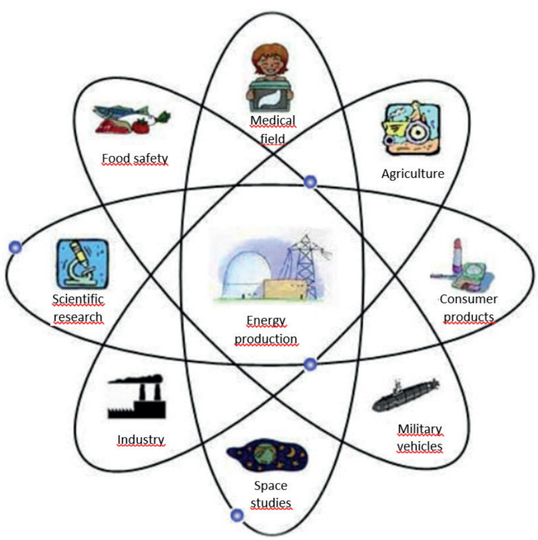
2.2. Structure of Nuclear Energy

Due to the weight of the atoms in uranium, it stores quite compactly. Uranium's heavy particles have a natural tendency to want to separate and reduce themselves to smaller volumes. The energy that emerges when atoms scatter during division is called nuclear energy (Encyclopaedia Britannica, 2019). If the number of nuclei that can be disintegrated in the structure and the distribution of these nuclei within themselves and the number of neutrons released from disintegration are kept under control, continuous and controlled energy can be achieved, as in nuclear power plants. In such plants, it is possible to produce electrical energy in a controlled manner in line with the need. Since atoms hit other nuclei during this splitting event to become stable, they also activate them and cause them to split. In this way, they can provide a high amount of continuous energy.

2.3. Uses of Nuclear Energy

Modular reactors, developed in small structures to meet various energy needs, have started to become a reality. Increasing global energy demands due to population growth and economic expansion, increasing urbanization and industrialization, and higher demands necessitate better use of existing energy resources. Studies continue for changes in strategic energy needs and the creation of new energy sources. Currently, about 20 small reactor designs are being developed in 10 developing countries around the world: namely, India, Argentina, China, France, South Korea, Italy, Japan, the United States, South Africa, and the Russian Federation. These countries have focused on developing micro-scale applications of nuclear energy. Recently, many applications have emerged regarding portable and portable nuclear reactors. A small yet safe reactor called NuScale produces 60MW of electricity. Thanks to its integrated and modular design and cooling system, the reactor can accommodate many positive features at the same time. Its core can be changed after as long as 24 months (Geoffrey et al., 2019). Figure 1 shows other valuable areas of nuclear application, including medicine, agriculture, food safety, consumer products, scientific research, space studies, military vehicles, and industry. In Figure 1, the main usage areas of nuclear energy are given.

Figure 1. Nuclear Energy Usage Areas



Reference: (Web I, 2019)

The development of small-sized reactors has brought with it the problem of licensing, and modular design licenses have been started to be granted for reactors defined as advanced reactors producing up to 300MW of electrical power (Alam et al., 2020). There are many driving forces in the development of such reactors. High flexibility in meeting energy needs, power generation for a wider range of users and applications, seeking alternatives to fossil fuels nearing the end of their life, meeting energy needs with the characteristics of increasing natural and passive safety and performance, low capital coverage, suitability for cogeneration and non-electrical applications, options for physically less developed remote regions (which can be easily coupled with the systems infrastructure), and hybrid energy systems, including renewable resources, have spurred the trend of combining nuclear and alternative energy sources (Alam et al., 2020). The emergence of new designs to meet safe and economically viable needs greatly increases the demand for 300KW nuclear power reactors (Iaea, 2018).

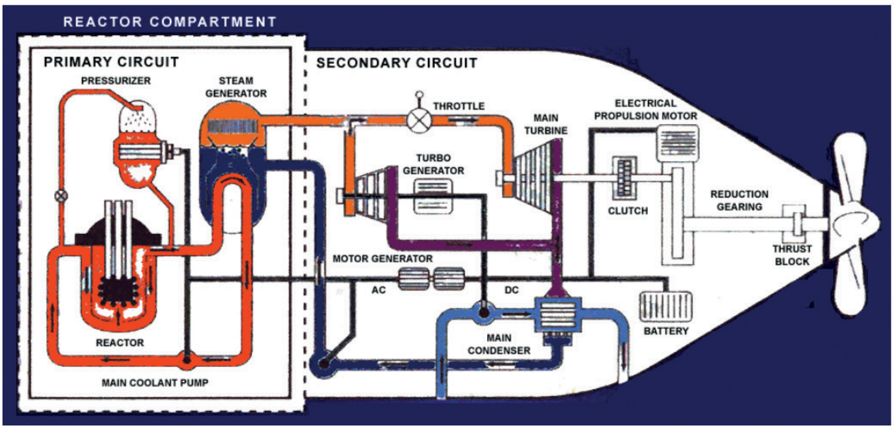
2.4. Nuclear Power Systems on Cruises

When designing a cruise ship, the reactor must have a dedicated area for installing such components as the high-strength steel reactor vessel, heat exchangers, steam generators, steel pipes for the transfer of hot and cold water, durable pumps, and various valves (Schøyen & Jensen, 2017). Because the system produces high levels of heat and radiation, the protection of the crew and guests is of vital importance. More than 100 tons of lead shields are placed around each reactor system.

A pressurized water reactor with two basic structures is used—one as the main and the other as the secondary system—for the propulsion systems that will work with nuclear energy to be used in the cruise ships (Invernizzi et al., 2017). The primary system circulates normal water and consists of pipelines, pumps, and steam generators, which are the contents of the reactor. The water is continuously circulating as the heat produced in the reactor is transferred to the water under high pressure to cool the reactor and prevent it from heating at the same time. This water is pumped back into the reactor for heating and recycled by steam generators. In steam generators, heat from the water in the primary system is transferred to the secondary system to form steam. The secondary system is isolated from the primary system by means of separators so that the water in the two systems does not mix.

In the secondary system, steam is directed to the main propulsion turbines, which drive the steam generators and propellers to rotate the turbine alternators that supply electricity to the ship. After the steam passes through the turbines, it is condensed into the water fed back to the steam generators by feed pumps and converted back to water (Simonsen et al., 2019). For this reason, the primary and secondary structures are closed-loop systems in which the water is circulated and regenerated primarily hot and then cold. Since there is no situation that requires the creation of air and oxygen for combustion, it is possible for cruise ships running on nuclear power generation systems to operate independently for a long time. The system needs only water, which is immediately accessible to cruise ships by default (Iaea-Tecdoc-1854, 2018). The above-mentioned system is shown in Figure 2.

Figure: 2 Nuclear Powered Ship Power Systems



Reference: (Web II, 2022)

The energy-generating parts of nuclear-powered ships continue to be sources of radiation even after the ships have completed their service and the plutonium rods have been removed from them. Fusion rods that are inactive should not be abandoned to nature but should continue to be stored in dedicated containers. Since the water used for the cooling of the core in the ship is exposed to radiation, it should not be released into the environment. Therefore, the pipes in the system should be separated from the other materials in the same way (Sanders & Sanders, 2019).

2.5. Nuclear Energy and Cruise Ship Applications

The use of nuclear energy in cruise and commercial ships provides flexibility in ship design because of its small footprint. Because the ship requires less refuelling, it can continue on its way for a long time without stopping at ports. For commercial ships, on-board nuclear energy systems are simple, safe, and compact, allowing extra room for transport (Hirdaris et al., 2014). The first generation of nuclear-powered ships has come a long way in terms of safety (Magwood, 2001). People's trust can be gained by high security levels, increased experience, advances in nuclear energy control, sound engineering practices, and lessons from negative experiences (Freire & Andrade, 2015). However, security measures should not be neglected. Today, fossil fuels have established themselves in the world and continue to be the most widely used energy source. Nuclear-fuelled ships will be able to provide the same confidence in the future. The use of low-enriched uranium on NS *Savannah*, seen in Photo 1, provided more reliability (Armellini et al., 2018) and made it the new standard of shipping in the 1950s when it was built (Lange, 1990). The world's first nuclear-powered surface ship, which entered service in 1959, served until 1989 and was discontinued over its hull thinning due to ice erosion. As a result of engineering calculations under normal conditions, the ship, which was designed for a reactor life of 100,000 hours, was deemed appropriate to be used for more than 30 years. It has travelled more than one million nautical miles in this period of use, thus demonstrating that nuclear-powered marine engines have higher operational reliability than their diesel counterparts (Gravina et al., 2012).

Photo: Nuclear ship 01 Savannah

Reference: (Web III, 2019)

A cruise ship needs to be refuelled on average every eight months, but there is no need for inspection, maintenance, or replacement of the core inside a typical commercial nuclear ship reactor. When the characteristics of the *Anthem of the Seas* cruise ship are examined, we find that the ship requires 4 x 4694 = 18,776 horsepower at full load. Converted into megawatts, it puts out approximately 14MW. Since the NuScale modular reactor produces

60MW of energy, it can be said that even the world's largest cruise ship, *Symphony of the Seas*, can fulfill its energy needs.

3. Conclusion

The increase in global greenhouse gases due to carbon dioxide emissions, the ever-increasing population rate, the use of fossil fuels by ships, and the consumption of hydrocarbon fuels intensify today's search for energy in different areas. For the sake of our collective future, hydrocarbons must be reduced. Besides clean and renewable energies, the use of nuclear energy and power generation is inevitable.

Since nuclear energy produces more power than water, hydrogen, solar, and wind energy generation systems and produces almost zero carbon dioxide emissions, it has the capacity to fill the gap caused by the depletion of fossil fuels. Although it is used for defence power in military ships, submarines, and aircraft carriers today, one should not be surprised to see nuclear reactors being used in cruise, commercial, and container ships in the near future. Enhanced security measures and well-established peaceful engineering measures are the most important practices for its success.

For the use of nuclear-fuelled ships and cruise ships, nations should come together and provide the necessary support by basing their peaceful use of nuclear power on a universal legal procedures and rules. Countries should prepare for the development of nuclear energy by establishing common areas for clear and joint reflection on the requirements of the world's future fuels. Targets should be set to pave the way for tourists and guests to benefit from recreation areas in accordance with the rules and frameworks of international law for nuclear ships to dock at ports and navigate the seas. Although the initial investment cost of nuclear energy is high at the moment, it guarantees a long ship life (at least 30-40 years). For this reason, the service life of the cruise ships and other ships to be produced should be well calculated, and designs should be made that can benefit economically from all of the energy for years. Making use of nuclear energy in the determination of sustainable tourism targets should be among the priority targets in the development plans of all nations.

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