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Feasibility Study on Nuclear Propulsion Ship according to Economic Evaluation

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1. Introduction

The nuclear propulsion ships (hereinafter referred to as "nuclear ships") have recently grown in importance as an eco-friendly ship. The use of nuclear ships has been extending to the icebreaker, the deep-water exploration ship, and the floating nuclear power plant.

Prior to developing the new ship, the relevant regulations need to be considered. In this study, we reviewed the nuclear ship-related regulations.

In addition, economic value is one of the most important factors which should be considered in the pre-design phase. To evaluate the economics of the nuclear ship, we calculated Capital Expenditure (abbreviated as CAPEX) and Operation Expenditure (abbreviated as OPEX) for various types of ships.

2. Nuclear ship-related regulations

Most of the nuclear ship-related regulations are based on the SOLAS 1974 Convention of IMO (International Maritime Organization) [1]. Especially, the chapter 8 deals with the requirements during construction and operation of the nuclear ship such as approval of reactor installation, radiation safety, and operating manual, etc. To supplement the requirements of the chapter 8, "Code of Safety for Nuclear Merchant Ships (resolution A.491)" is recommended. The code provides the design criteria, ship design, and construction, etc.

In domestic law, Atomic Energy Law is focused on regulating the arrival and departure of foreign ship [2]. The reason is that there is no nuclear ship in Korea. The domestic law related to the nuclear ship needs to be established prior to developing the nuclear ship.

Classification societies from all over the world have their own rules related to the nuclear ship. Especially, "Rules for the Classification and Construction of Nuclear Ships and Floating Facilities," one of RS rules, is worth considering [3].

3. Economic evaluation

In this section, we evaluated and compared the economics for the nuclear ship and the ship with the diesel engine (hereinafter referred to as "diesel ship"). As a methodology, Discounted Cash Flow (abbreviated as DCF) was used.

3.1 Conditions of ship used for evaluation

For our evaluation, we considered the container ship of 14,000 TEU in size. It spends a lot of fuel oil during the voyage. Especially when the ship follows the route between Asia and Europe, it passes through Emission Control Area (abbreviated as ECA). IMO regulates the emissions of SOx in ECA. The fuel oils with low sulfur like Marine Diesel Oil (abbreviated as MDO) and Marine Gasoline (abbreviated as MGO) should be used in these regions. The prices of MDO and MGO are higher than Heavy Fuel Oil (abbreviated as HFO), which causes the rise in OPEX.

3.2 Economic analysis method

To evaluate the economics, we calculated the CAPEXs of both types of ships and subtracted the CAPEX of the diesel ship from one of the nuclear ship. The calculated value is considered as the initial investment. The similar calculation applies to the OPEX as well as the CAPEX. The difference calculated from the OPEX is considered as the annual profit.

Net Present Value (abbreviated as NPV), Internal Rate of Return (abbreviated as IRR), and Payback Period (abbreviated as PP) was used as the value evaluation method.

3.3 Cost estimation

The fuel consumption of the diesel ship according to the sea routes was calculated. When the diesel ship sails 25,000 NM (Nautical Mile) between Asia and Europe for 56 days, MDO of 38,527 ton/year in ECA and HFO of 50,648 ton/year in the rest area is spent.

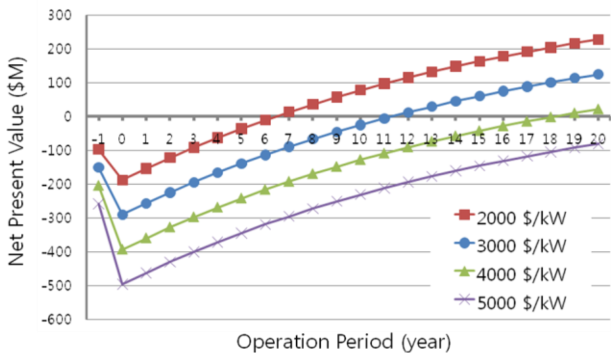

Fig. 1. NPV vs operation period for cost of nuclear reactor

Table 1 Calculation of cost[1)]

		Diesel ship	Nuclear ship	Difference	Reference
CAPEX ($M)	Main Engine	18	270	252	• Diesel engine: 300 $/kW • Nuclear reactor: 3,000 $/kW
	Contingency		27	27	10% of Engine cost
	Increased CAPEX			**279**	
OPEX ($M/year)	Fuel Cost	68		68	• HFO: 631 $/ton • MDO: 934 $/ton
	Fuel Cycle Cost		30	30	• Referred from MRX [4] • Fuel consumption: 3.663 ton/year[2)]
	Fuel Exchange Cost		0.2	0.2	
	Waste Disposal Cost		0.9	0.9	
	Crew Expenses	1	1.3	0.3	
	Insurance		1	1	
	Saved OPEX			**36**	

1) The figures shown in the table should be regarded as "Reference Only" without absolute commercial meaning.
2) The fuel consumption was calculated based on the fuel cycle of the SMART reactor developed by KAERI, which is used to calculate the fuel cycle cost according to the formula of the MRX [4].

The CAPEX and OPEX for the diesel ship were calculated according to the aforementioned condition. In case of the nuclear ship, we calculated both of them based on the information of MRX [4]. The result is shown in Table 1. As mentioned in Table 1, the CAPEX of the nuclear ship is higher than one of the diesel ship by 278.9 million dollars. The OPEX of nuclear ship is lower than one of the diesel ship by 35.9 million dollars per year.

3.4 Sensitivity study

In the previous section, the cost of the nuclear reactor was assumed to be 3000 $/kW. The additional calculation was performed for the sensitivity analysis according to the cost of the nuclear reactor. We calculated the CAPEX and the OPEX of the nuclear ship in the same way as Table 1 for the following cases: 2000, 4000, and 5000 $/kW. The four curves in Fig. 1 are the NPV as a function of the operation period for the nuclear reactor with different costs.

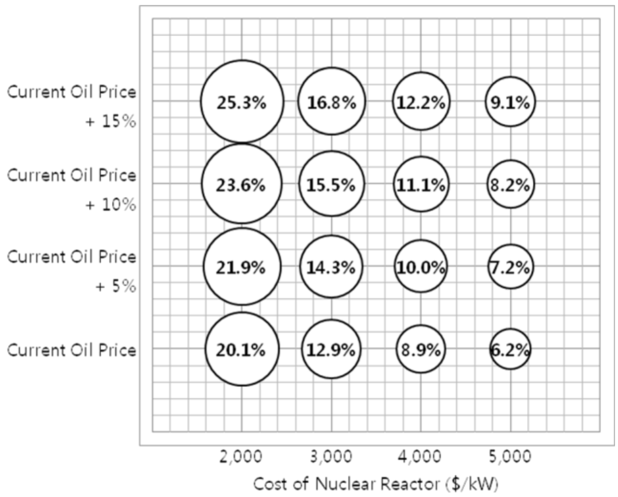

Fig. 2. IRR according to the cost of the nuclear reactor and the oil price. The area of each circle corresponds to the IRR.

When the cost of the nuclear reactor is 3000 $/kW, the PP is 11 years and the NPV is 124 million dollars after 20 years. As the cost rises, the PP increases whereas NPV decreases. Figure 1 shows that the economic feasibility is guaranteed when the cost of the reactor is less than 4000 $/kW, which can vary from the oil price.

Accordingly, the sensitivity analysis by change of the oil price was performed. When the oil price goes up from 5% to 15%, the CAPEX and the OPEX was calculated. This calculation result was combined with the data of Fig. 1. As seen in Fig. 2, the IRR is 12.9% at the current oil price when the cost of the nuclear reactor is 3000 $/kW. Even though the cost of the nuclear reactor goes up to 4000 $/kW, the IRR at 15% more than the current oil price is 12.2%, which is similar to the mentioned case.

4. Conclusions

We reviewed the nuclear ship-related regulations and evaluated the economics of the nuclear ship compared to the diesel ship. The calculation result shows that economic feasibility of the nuclear ship depends on the oil price as well as the cost of the nuclear reactor. The additional research for various types of ships needs to be performed in the future.

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