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Nuclear power for the Europa, an oxygen and water planet, to the third space colony construction: Inspirations from Texas A&M Univ. incorporated with NASA

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1. Introduction

Exploring the solar system, the energy source is investigated for atomic power where the undersea nuclear power plant (NPP) is adequate in the Europa, a satellite of Jupiter. It is imagined for NPP in the Europa where new space colony is proposed for the human civilization. Considering the environment of this remote planet, the gas cooled reactor (GCR) could be designed in the future in which the modified reactor cavity cooling system (RCCS) is applied to the study. In the aspect of the coolant based thermohydrulics, the buoyancy force could remove the residual heats as well as the fission fragments in the time of the severe accident where the core could be melted and the plant is in an extremely dangerous situation. Fig. 1 has the diagram of the orbit of Jupiter and Europa in the Solar system, in which three moons exist.

2. Methods and Results

For challenging the construction of the facility as this unattempted trial, it is important to make use of the particular environmental characteristics in the Europa. One of important things is to consider the gravity diversification where non-Earth gravity should be calculated in the related equations, which is in Fig. 2. Furthermore, the thick ice lay could be used for the radiation shielding for the solar and Jupiter's radiations where this could be used as the fixed holder for NPP. So, the reversed shape position of the plant is designed.

There is the list for the Europa in Table I where the orbit properties and atmospheric characteristics with gravity are shown (NASA, 2007; Pappalardo et al., 2008; Yeomans, 2007). The meaning of nuclear energy development is due to the very weak solar energy to use for the mass energy production in the space colony. The solar energy comparison between Earth and Jupiter is variable by distances from the Sun as follows,

$$\frac{\frac{1}{Surface\ of\ the\ distance\ circle\ from\ Sun\ to\ Jupiter}}{\frac{1}{Surface\ of\ the\ distance\ circle\ from\ Sun\ toEarth}} = \frac{\frac{1}{4\pi R_1^2}}{\frac{1}{4\pi R_2^2}} = \frac{1.00Au^2}{5.20Au^2} = 0.03698 = 3.698\ \% \quad (1)$$

Hence, the solar energy on the Jupiter is about 3.7% of that on the Earth. There are some particular features in Europa environment. Fig. 3 is the schematic of Europa (Williams, 2015) where the thicknesses of icy and ocean layers are shown (NASA, 2012).

2.1. Europa high-temperature gas-cooled reactor (EHTGR)

For the harsh planet of Europa, it is imagined to construct the high-temperature gas-cooled reactor (HTGR) in Europa, which is supposed to be named as Europa high-temperature gas-cooled reactor (EHTGR). The reversed shape position of the plant is seen in Fig. 4. In fact, the 'Reverse' means just the case of the viewpoint of the Earth. In other planet, the inertial system is totally different. The gravity is lower than that of Earth, which could make the anti-gravity system operate in the water. This is reasonable to fix the plant to the inside surface of ice layer which could be 25 kilometers' thickness.

2.2. Europa reactor cavity cooling system (ERCCS) with buoyancy

As a famous accident prevention system, the reactor cavity cooling system (RCCS) is made for passive system in the HTGR. Similarly, it is proposed that Europa reactor cavity cooling system (ERCCS) in which the buoyancy is considered as the mass power generations in Fig. 5. The gap in the ice layer could be the cavity of the cooling for the NPP where the naturally made duct could absorb the heat from the NPP in the emergency situation. There are some descriptions to the system (Nave, 2017),

$$\text{Buoyancy} = \text{The weight of displaced fluid} \quad (2)$$

If one uses gravity in the planet, which is calculated as follows (Mastin, 2009),

$$\text{Gravity} = \text{G}\frac{Mm}{R^2} \quad (3)$$

The density of the planet is assumed to be equal everywhere. So (Photon blog, 2009),

$$M = \frac{4}{3}\pi R^3 \times \text{density} \quad (4)$$

$$\text{Gravity} = \text{G}m\frac{4}{3}\pi R \times \text{density} \quad (5)$$

Then, the gravity decreases linearly as the length of r decreases in Fig. 6. The net force of the buoyancy is as follows,

$$F = mg - \rho_f V_{disp} g \quad (6)$$

where ρ_f is the fluid mass density, V_{disp} is the volume of displace body of fluid, m is the object mass, and g is the gravitational acceleration. Then, the velocity is,

$$\text{Velocity} = F \times Time/m \quad (7)$$

$$\text{Velocity} = (m - \rho_f V_{disp}) g \times Time/m \quad (8)$$

Fig. 7 shows the comparisons between RCCS and ERCCS (Takamatsu et al., 2016). In Fig. 7(a), the heat transfer scheme in HTGR is seen as the heat of the reactor vessel transfers to the RCCS panel by the radiative heat transfer. Then, this heat goes to the outside gas as the inlet air where the natural circulations are done. The radioactive material would be out through the gap cavity in the ice layer. Finally, the fission fragment based material will be in the space altitude. The high level nuclear material expelled from the nuclear accident could fly outside of the Jupiter orbit. In Fig. 7(b), there are the comparisons of the convection heat transfers. In Fig. 8, the comparisons of buoyancy velocity are described. It is up to about 50% more around surface. In the case of Earth, the buoyancy velocity is not changed much which is seen in Fig. 8(b) where the difference of gravity between surface and 25 km deep position is 1.67138E-05 %.

2.3. Accident Analysis

If the accident of the EHTGR happens, the actions of convective heat transfer and fission fragments leak are the most important issues in the safety feature, which is caused by the particular geometry of the Europa where the negligible atmosphere and the thick ice cover are formed. The pooling boiling provokes the convective hear transfer where the buoyancy initiated bubbles are going to be floating and expelled to the outer space in very fast manners seen in Fig. 8 (a). Therefore, the ERCCS could be done successfully by the gravity induced operations where the smaller planet radius makes the higher gravitational variations comparing to the case of the Earth. The speed of bubble is faster about 50 % than that of the starting point.

3. Results

It is analyzed for an accident of imaginary NPP in Europa happens as the modified RCCS. The buoyancy force is very important for the residual heat removal as well as the fission fragment expellant at the severe accident where the core could be melted and the plant is in extremely dangerous situation like the Fukushima and Chernobyl nuclear disasters. The buoyancy velocity is up to about 50% much faster around surface comparing to that of Earth. The cooling capability of the RCCS in this imaginary NPP is able to be satisfied successfully.

4. Conclusions

It is meaningful to imagine the non-conventional NPP where the other kind of environment should be considered in the aspect of the thermohydrualics with safety focused imagination. The 3rd planet for the human's colony is supposed following that of Moon (Earth) and Mars. Fig. 9 is the proposed grand constructions for atomic power in solar system where regolith cooled lunar reactor, gas cooled Martian reactor, and gas cooled spherical reactor (Woo et al., 2011; Woo, 2014a,b; Woo et al., 2014). It is suggested for the best way for public acceptance by space nuclear powers, which is in Fig. 10. The alternative nuclear energy for space power is in Fig. 11, considering the policy of shrinking governance of nuclear energy development in South Korea.

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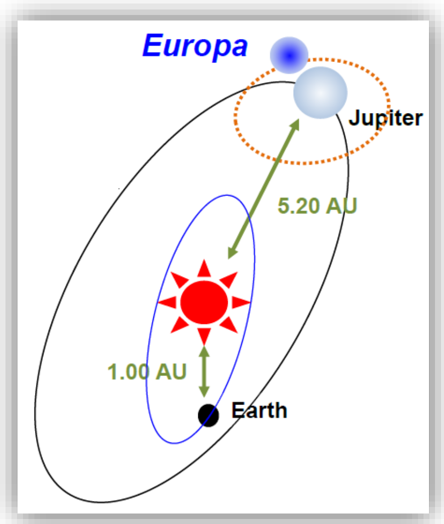


Fig. 1. Diagram of the orbit of Jupiter and Europa in Solar system (Williams, 2015).

Fig. 2. Characteristics of a new planet.

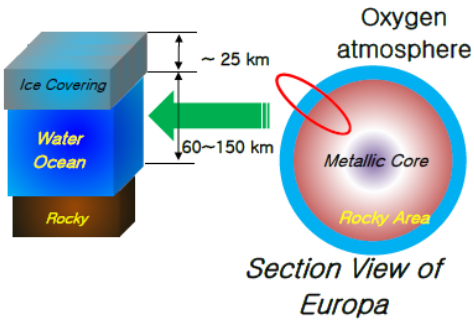


Fig. 3. Schematic of Europa (NASA, 2012; Williams, 2015).

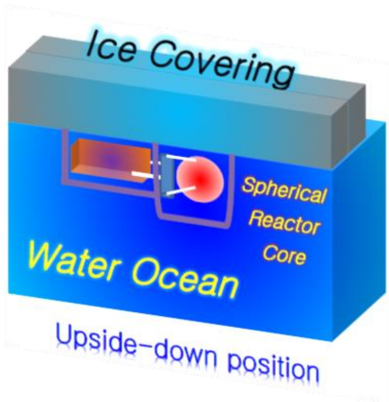


Fig. 4. Concept for reactor under the sea (NASA, 2012; Williams, 2015).

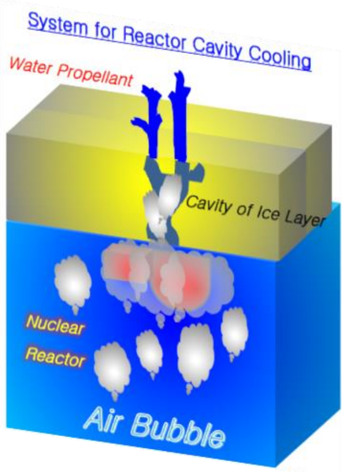


Fig. 5. System for reactor cavity cooling system (RCCS) with buoyancy in Europa (Nave, 2017).

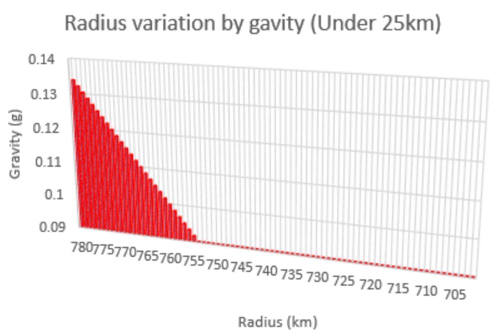
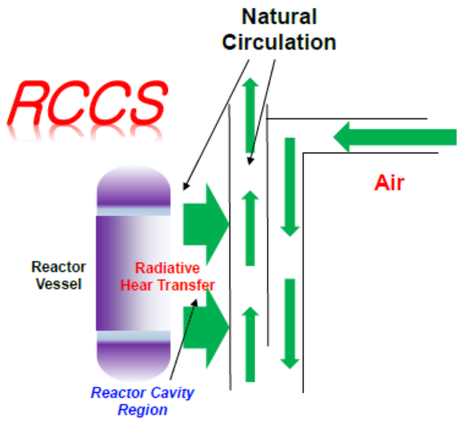
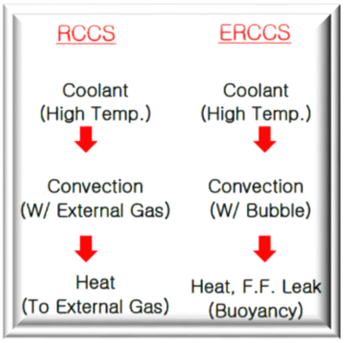


Fig. 6. Gravity changes by radius.

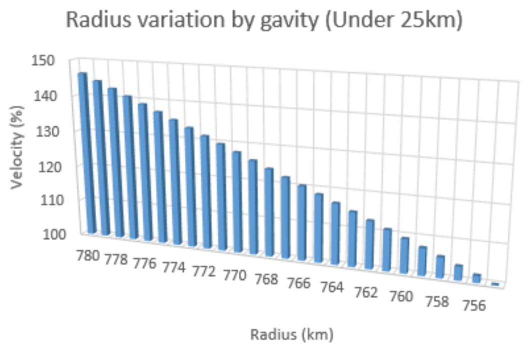


(a)

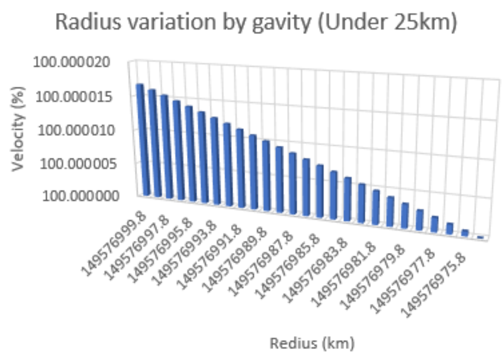


(b)

Fig. 7. Comparisons between RCCS and Europa reactor cavity cooling system (ERCCS) as (a) Convection of RCCS and (b) Comparisons of the convection heat transfers (Takamatsu et al., 2016).



(a)



(b)

Fig.8. Comparisons of buoyancy velocity between (a) Europa and (b) Earth.

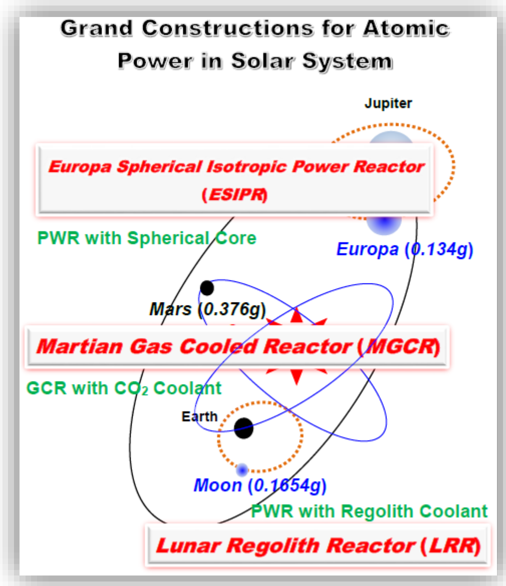


Fig. 9. Grand constructions for atomic power in solar system.

Fig. 10. Best way for public acceptance by space nuclear powers.

Fig. 11. Alternative nuclear energy for space nuclear energy.

Table I. List for Europa (NASA, 2007; Pappalardo et al., 2008; Yeomans, 2007)

Variable	Content
Discoverer	Galileo Galilei
Discover date	Jan. 8, 1610
Periapsis	664,862 km
Apoapsis	676,938 km
Orbital period	3.55118 days
Avg. diameter	1,560.8 ± 0.5 km (0.245 times of Earth)
Surface	3.090 $\times 10^7$ km^2 (0.061 times of Earth)
Mass	4.799844 $\times 10^{22}$ kg^3 (0.008 times of Earth)
Gravity	1.314 m/s^2 (0.134 g)
Surface Temperature	102 K (50 ~ 125 K)
Atmosphere	Oxygen
Atmospheric pressure	0.1 µPa(10^{-12} bar)