Atomic-Powered Space Elevator for Cheaper Journey to the Moon Inspired by NASA Innovative Advanced Concepts (NIAC): Revolutionary Boosting Strategy for the Global Nuclear Industry

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1. Introduction

The space elevator is proposed for the atomic energy-based journey by the cheaper operations where the moon is the primary destination in this study. A Russian scientist Yuri Artsutanov designed a new concept of the space elevator in 1957 [1]. Following the nuclear-boosting strategy, Fig. 1 shows the new strategy for global nuclear industries in which the new kind of direction is seen in nuclear energy promotions. Therefore, the alternative use by electricity generations of the small modular reactor (SMR) can produce hydrogen production and desalination followed by the atomic-powered space elevator in Fig. 2.

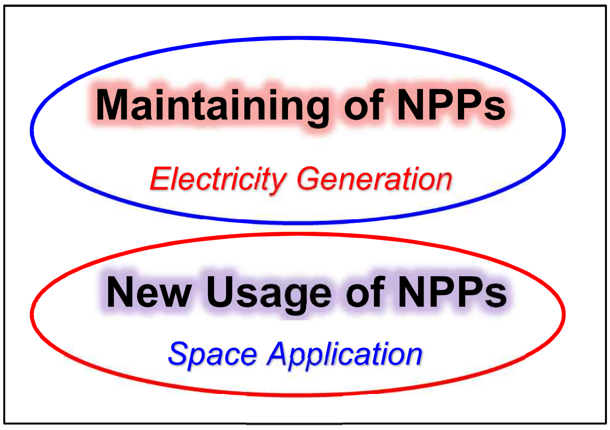

Fig. 1. New strategy for global nuclear industries.

Fig. 2. Alternative use of SMR.

The configuration of the space elevator on Earth's side is shown where the elevator is located on the equator in Fig. 3. There is a counterweight attached to the surface of the Earth. Fig. 4 shows that the station (Station1) over the geostationary orbit (GEO) is the place for the passenger transfers from the elevator to the shuttle to the lunar station (Station2) and then it is transferred from the shuttle to the lunar elevator on the lunar station. It is proposed to use the SMR to produce the electricity in the Earth elevator and to use the 10-kilowatt class fission surface power system of the Kilopower Reactor Using Stirling Technology (KRUSTY) in the lunar elevator. In the previous study, Nixon et al. worked on the material property of the space elevator [2]. Shi et al. studied the liberation and stabilization of the space elevator system [3].

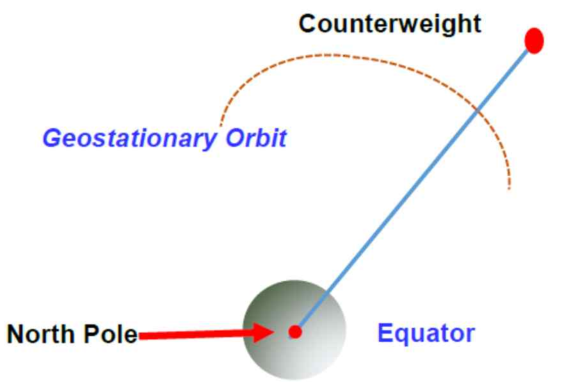

Fig. 3. Configuration of space elevator in Earth.

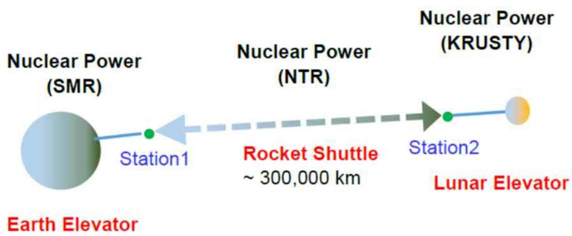

Fig. 4. Travel to the moon for the public traffic.

2. Methods

The basic structures of the space elevator are the force balances of the space elevator, the space shuttle between Earth and the moon, and the counterweight. The space elevator is set by the force balances of the space elevator where the gravity is offset with the centrifugal force. The elevator's cable is tightened by the force balances of gravity and centrifugal force. The geosynchronous equatorial orbit (GEO) is formed at the point of the force balance [4].

The situation of the gravitational space of two massive orbiting bodies is called the Lagrange point of equilibrium for small-mass objects. The restricted three-body problem could be solved by this matter [5]. The force of gravity g and the centrifugal acceleration F_c are,

$$g + F_c = -\frac{GM}{r^2} + u^2 r \quad (1)$$

where g is the acceleration of gravity (m/s^2), F_c is the centrifugal acceleration along the vertical cable (m/s^2), G is the gravitational constant (m^3/(s^2 kg)), M is the mass of the Earth (kg), r is the distance from an altitude to the Earth's center (m), and u is Earth's rotation speed (radian/s). The altitude of GEO is obtained as 35,786 km above Earth's surface as follows [6]. Then, the altitude of GEO, r, is,

$$r = \left(\frac{GM}{u^2}\right)^{1/3} \quad (2)$$

For the other planet, it is compared with the case of Earth as follows,

$$\frac{r_n}{r_E} = \frac{\left(\frac{GM_n}{u_n^2}\right)^{1/3}}{\left(\frac{GM_E}{u_E^2}\right)^{1/3}} = \frac{\left(\frac{M_n}{M_E}\right)^{1/3}}{\left(\frac{u_n^2}{u_E^2}\right)^{1/3}} \quad (3)$$

If $r_E = 1$, it is described that the relative distance to the Earth's case for the case of Rotation Speed Same as Earth and for the case of Planet Mass Same as Earth. The regions of possible distance in altitude of GEO are seen in Fig. 5 where the regions are located between two graphs. So, the mass effect could increase the distance much more than the case of the rotation speed.

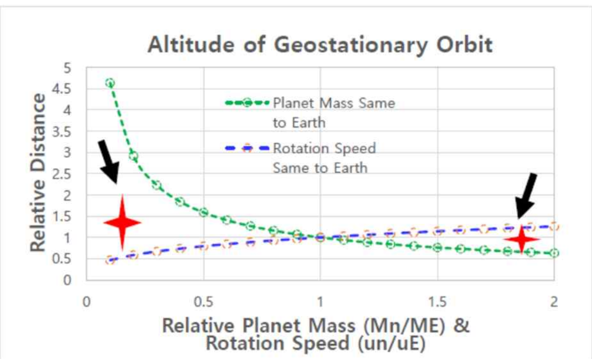

Fig. 5. Altitude of Geostationary Orbit for regions of possible distance.

The mechanics of the space elevator is shown as follows in which the forces are balanced in Fig. 6,

$$\text{Balanced Force} = -g + P \quad (4)$$

It goes up to the station on the GEO in the positive value. The friction of the elevator car could be considered negligibly compared to the gravity force. It is difficult to pull up over the long length of 35,786 km. It is possible to make several interim stations. Furthermore, the vacuum in the cable could pull up the elevator at a fast speed such as a vacuum-tube train where the speed might get to 1,000 km/h [7].

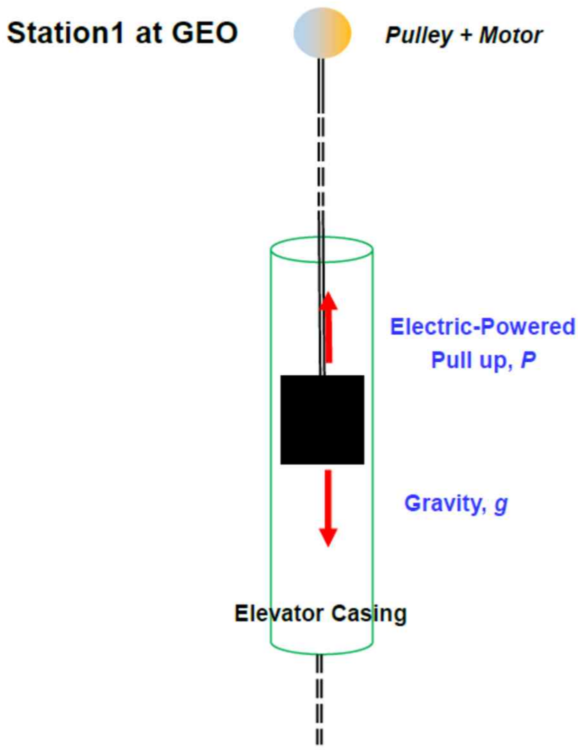

Fig. 6. Mechanics of space elevator.

The gravitational potential energy in geosynchronous orbit (GSO) is about 50 MJ (15 kWh) per kilogram [8,9]. The SMR of 100 MWe is proposed as the compact and enhanced safe type of nuclear power plant (NPP). Table 1 is the list of candidate SMRs for space elevator [10]. By electricity prices for 2008 to 2009, and the current 0.5 % efficiency of power beaming, the electrical cost of a space elevator is about $220/kg. Dr. Edwards mentioned the efficiency could increase to 2% [10,11].

Table I: List of candidate SMR for space elevator [10].

Name	Power(MWe)	Producer	Status
ARC-100	100(SFR)	ARC Nuclear(Canada)	Design
OPEN100	100(PWR)	Energy Impact Center(USA)	Design
NuScale	77(PWR)	NuScale Power LLC(USA)	Licensed
Polls-Royce SMR	470(PWR)	Rolls-Royce(U.K.)	Licensing

3. Results

If one uses the speed of 300 km/h like the Korea Train eXpress (KTX), it will take about 5 days to climb to GSO which is the same as GEO in the equator of Earth [11] as follows,

35,786 km (The altitude of GEO) / (300 km/sec)
= 4.97 days (5)

In the lunar elevator, if the speed is the same as 300 km/sec, it takes 3.61 days as follows,

26,000 km (The altitude of lunar GEO) / (300 km/sec)
= 3.61 days (6)

The average Earth-Moon distance is 384,400 km. There is a list of nuclear thermal rocket (NTR) velocities (Solid core, 450 MWth, Isp = 900 sec., Nominal core temp. = 2,750 K) in Table 2 [12]. If one uses the H_2 gas NTR, it takes about 11 hours. Using conventional rockets, it takes several days in the period of space travel to the moon by chemical propulsion fuels. Some materials for the space elevator are in Table 3 [13]. The carbon nanotube has a higher breaking strength which gives the candidate of the cable of a space elevator. So, the period of travel to the moon takes about 10 days' one-way trip.

Table II: List of nuclear thermal rocket (NTR) velocity (Solid core, 450 MWth, Isp = 900 sec., Nominal core temp. = 2,750 K) [12].

NTR exhaust gas	Velocity (km/s)
H_2	8.093
CO_2	3.306
CH_4	6.318
NH_3	5.101

Table III: Specification of cable material for space elevator [13].

Material	Density(Kg/m^3)	Breaking Strength(N/m^2)	Specific Strength(m/kg)
Steel	8,000	5.0×10^8	6.25×10^4
Carbon Nanotube	1,000	6.0×10^{10}	6.0×10^7
Carbon Fiber	1,750	4.3×10^9	2.5×10^6

4. Conclusions

It is designed for the space elevator of public purpose as an economic travel to the moon or space. Speed and material are important in space structures where space life could be one of the usual human lifestyles. The safety of the elevator and shuttle should be considered very important in the operations. In addition, the vehicles should be sturdy and radiation-proof. An extra rocket for the emergency escape is necessary. The operations of space elevators are in close surveillance in the Earth base, stations, and moon base. The nuclear-powered elevator and rocket could be applied to other travel plans to Mars or deep space journeys in the future.

Acknowledgments

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