ANALYSIS OF TERRAFORMING ON MARS USING NUCLEAR POWER FOR THE BEGINNING OF SPACE COLONIZATION

by

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As a historic challenge for humans, Martian colonization has been initiated by nuclear energy. A moving nuclear power plant could be imaginable known as a nuclear reactor rover. The design of the nuclear reactor rover has been performed where the important matter is how to make the caterpillar move the reactor and its facilities. Hence the slider length and contact point are proposed. The normalized heat transfer is analyzed by slide length and contact point where they are normalized as 1.0 and 10.0, respectively. Although the slider length of the caterpillar is proportional to heat transfer, the contact point shows the adverse values. Longer slider length and less contact point could be the optimized heat production system by the caterpillar which is the additional heat source except the other nuclear reactor. Any other planet could be considered as a potential human colony using the nuclear terraforming technology.

Key words: nuclear reactor, terraforming, rover, human colony

INTRODUCTION

As a historic challenge for humans, Martian colonization has been initiated by nuclear energy [1]. Although there are skepticisms of the possibilities, it is reasonable to examine the technological aspects. The concept of terraforming of Mars is to adapt it to Earth's conditions such as the atmosphere, environment, and some other ecological variables [2, 3]. This would be the mimicking of the early conditions of Earth which were harsh and non-comfortable for biological creatures [4]. Hence it takes a very long time. However, it is one of the critical points to develop the new planet to reduce the timeline of the terraformation from a thousand-year scale to a several hundred-year scale or less.

Historically, astronomer Carl Sagan speculated on the terraformation of Venus in Science [5] where seeding or algae could change the environment of the planet. After that time, the United States National Aeronautics and Space Administration (NASA) proceeded to make the preparation studies. Considering the space planet, it is possible to classify it by temperature and water content. There are several types of planets of two directions of the planet types where the temperature and humidity are variables to consider for the planet environments. Hence, the warmer and wetter one could be better compared to a harsh planet with cold and dried states. If one would like to construct a new dwelling place, water and heat are essential for a new world to humans. The way to increase the atmospheric temperature is to make use of the greenhouse effect where the CO_2 has a major role of heating increment.

According to tab. 1, although the percentage of the CO_2 on Mars is comparatively higher than that of Earth, the quantity is very low [1]. Therefore, it would be necessary to produce the CO_2 from the frozen one in the dried ice formed at the poles. However, the content of atmospheric gases is much smaller than those of the Earth considering the atmospheric pressure of 0.6 kPa. Hence, it is necessary to find another option to increase the carbon content. It is possible to use a nuclear bomb to melt the ice and emit the CO_2 into the Martian atmosphere. According to Zubrin and McKay [6], it is believed that the CO_2 is in a volatile form as much as from 30-60 kPa in frozen or regolith form on the south pole. However, there are several options to release the CO_2 such as a mirror to use the sunshine, impact by asteroid, or halocarbon gases (chlorofluorocarbon

Table 1. Content of atmosphere

Content	Earth	Mars
CO_2	0.04 %	96.0 %
O_2	20.94 %	0.145 %
N_2	78.08 %	1.9 %
Pressure	101.3 kPa	0.6 kPa

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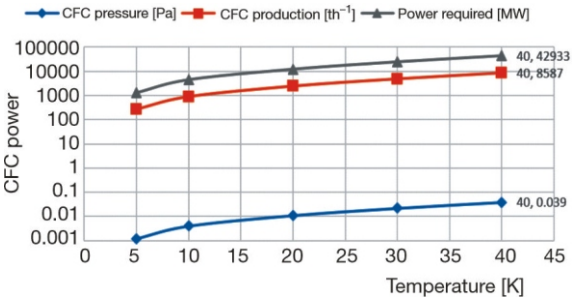

Figure 1. Configuration of temperature *vs.* CFC-power

(CFC)'s gases) by nuclear energy. If one were to think of nuclear energy in a very effective and possible way, it would need about a 1000 MW electrical type nuclear power plant (NPP) [6]. The relation between temperature and CFC-Power is given in fig. 1. It is possible to consider the temperature of creating atmospheric conditions.

METHODS

The construction of the artificial environment by the designed method has been proposed. The procedure of terraforming on Mars is the energy increase on the pole of Mars, the release of CO_2 in ice into the atmosphere, the warmer and thicker atmosphere, the stabilizing of atmosphere, and the creating of ecological systems. It would use nuclear energy to produce CO_2 which is iced on the south pole of Mars. It would be possible to use a nuclear bomb to melt the CO_2. There is a comparison between the moving nuclear power plant (MNPP) and the nuclear bomb for the usage in tab. 2. The grand finale of Cassini, the spacecraft orbiting Saturn, was aimed at avoiding radioactive contamination of the satellites including Enceladus, which was powered by 32.7 kg of Pu-238 [7, 8]. Therefore, it is not good to use the nuclear bomb's energy to melt the iced CO_2.

Melting methods

It is better to make use of the newly designed NPP. Figure 2 shows the imaginary view of the site on Mars where the CO_2 dried ice and NPP are designated around the south pole. There are two kinds of methods to melt the massive ice using a nuclear bomb in fig. 2(a) and nuclear reactor in fig. 2(b). With a nuclear bomb, it is done very quickly, but radioactive contamination is inevitable. On the other hand, using a nuclear reactor, the melting process is done slowly. In addition, the radioactive contamination is fortunately under control. According to fig. 1 where the power required is 42933 MW at 40 K, it is possible to increase the 40 K using about 43 units of 1000 MW electrical NPP. The Hiroshima type nuclear bomb can produce 84 TJ [9]. This is 84000 MW. Then, about 2 or 3 nuclear bombs are needed to melt the ice of the pole.

Table 2. Comparison between MNPP and nuclear bomb

Content	MNPP	Nuclear bomb
Power	Steady and stable	One impact
Range	Controllable	Very wide
Contamination	None	Very long
Cost	Higher	Lower

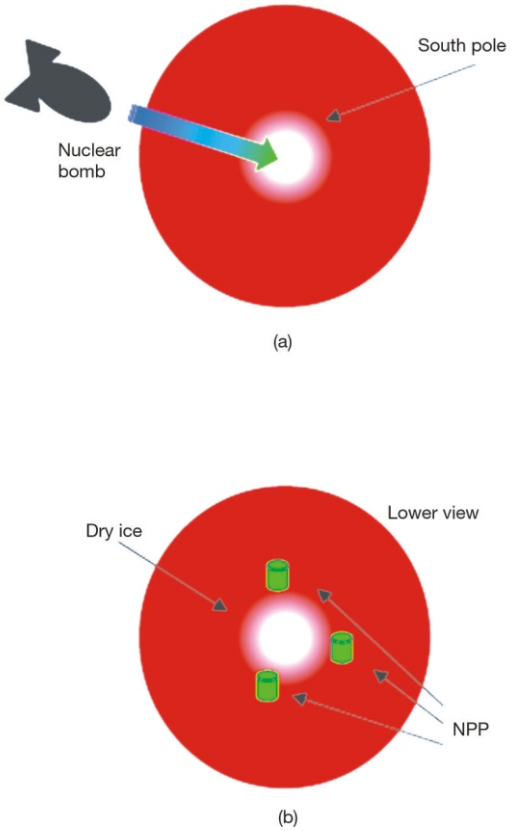

Figure 2. The melting methods for the massive ice; (a) nuclear bomb and (b) nuclear reactor

Nuclear reactor rover

There are wide-spread located NPP around the south pole. According to thermal efficiency, the output powers increase threefold. Hence, the proposed NPP is about 13 units which are one third of 43 units. Furthermore, the operation time also reduces the unit number. In the other case, an MNPP could be possible known as a nuclear reactor rover (NRR). Then, in the system, it is possible to make a new moving NPP type where the heat is transferred to the ice in the form of conduction. Figure 3 is the design of the moving NPP in which the reactor is moving and heat is transferred to the ice to melt and the CO_2 is emitted into the atmosphere in fig. 3(a). The caterpillar could work as infinitive tracking. The conductor pad could perform the heat transfer which is analyzed as the conduction to the ice surface. The track is shown in fig. 3(b) and the NRR goes downward in fig. 3(c).

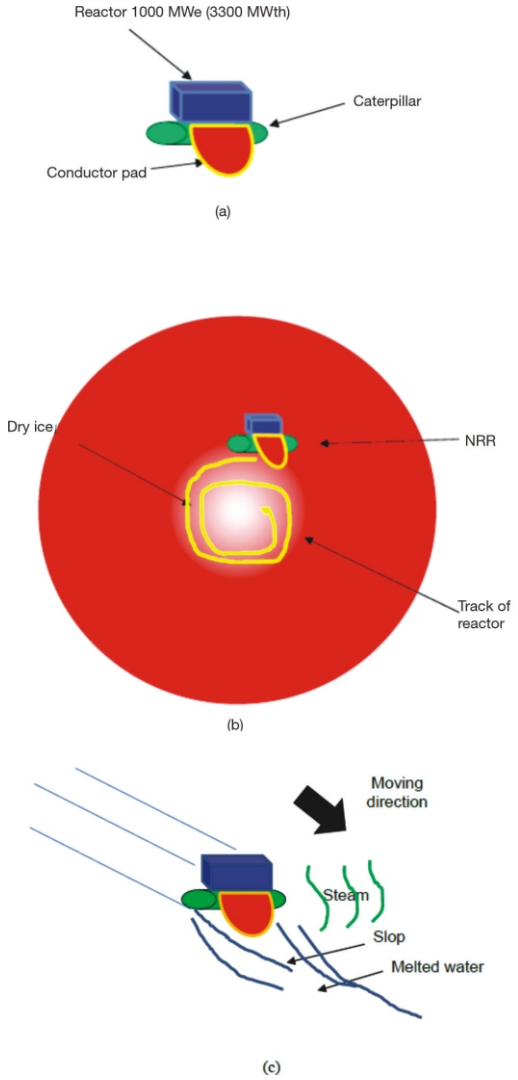

Figure 3. A new type of NPP; (a) NRR, (b) track of reactor, and (c) moving direction

Melting mechanics

Melting by the nuclear energy of reactor

There are two kinds of melting in the NRR system where the main heat is transferred by a nuclear reactor and the friction heat is done by caterpillar. The configuration of the NRR in which the reactor heat transfers on the ice surface by piping lines is shown. There is the typical heat conduction as

$$Q_1 \quad k\frac{\mathrm{d}T}{\mathrm{d}x} \tag{1}$$

where Q_1 is the heat flux, k – the thermal conductivity and $\mathrm{d}T/\mathrm{d}x$ – the temperature gradient. This is done as the hot water flows into the piping of the conduction part, which is simply made by the conventional technology by the heat transfer system.

Melting of friction energy by caterpillar

There is another heat transfer in the caterpillar as follows [10]

$$Q_2 \quad \frac{C_f F_{\mathrm{nor}} L}{p} \tag{2}$$

where Q_2 is the frictional heat, C_f – the coefficient of friction, F_{nor} – the normal force, L – the slider length, and p – the contact point. This is regarded as the total heat energy of thermal conducted away energy and remaining energy [10]. Hence, this makes the melting of the tracks, which is accelerated by the energy of the reactor.

$$Q_{\mathrm{tot}} \quad Q_1 \quad Q_2 \tag{3}$$

where Q_{tot} is the total heat produced by the nuclear energy and friction of the caterpillar.

Movement of the NRR

The movement of the NRR is done by the caterpillar output power and gravity on the slope which is made by the nuclear reactor energy and friction energy of the caterpillar. Then, the power of the system is

$$\text{Energy for movement}_{\mathrm{NRR}} \quad E_{\mathrm{cat}} \quad Q_1 \quad Q_2 \tag{4}$$

where Energy for movement$_{\mathrm{NRR}}$ is the total energy for NRR movement and E_{cat} – the energy for caterpillar operations. Hence the solar energy is not used for this system which is not effective considering the distance from the Sun.

RESULTS

The design of the NRR is performed where the important matter is how to make the caterpillar move the reactor and its facilities, although the major conductive heat transfer is made by the heat conducted part in fig. 3(c). Hence the slider length and contact point are proposed. Figure 4 shows the normalized heat transfer by slide length and contact point where they are normalized as 1.0 and 10.0 respectively. Although the slider length of the caterpillar is proportional to the heat transfer, the contact point shows the adverse values. Longer slider length and less contact point could be the optimized heat production system by the caterpillar which is the additional heat source except the other nuclear reactor.

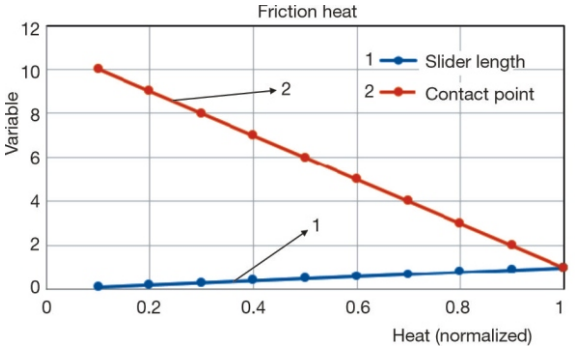

Figure 4. Normalized heat transfer by slide length and contact point

CONCLUSIONS

The nuclear energy needed to increase the atmospheric temperature for an ecological system creation has been examined. Nuclear terraforming is considered as the creating process of a new world as comfortable as the human can live (a habitable place for humans). In order to expedite new inhabitation construction, some further actions are necessary in Martian terraforming. The natural uranium could be carried from Earth in the initial stage. After surveying of Martian geology, a self-supply plant could be constructed for uranium or plutonium. It somewhat free of the worrying alleviates concerns about the radiation hazards to humans, because it is possible to start without the perfect radiation prohibition from NPP in the radioactive environment of Mars. The humanoid robotics could be substituted instead of humans in the very high radioactive areas [11]. This can make a better construction condition in the new colony economically due to the radiation safety cost savings. In addition, the magnetic field of Mars is much weaker compared to Earth, which can't catch the atmosphere content [12]. Therefore, the construction of the artificial magnetic field has been proposed where the energy should be supplied as another study topic in the future. Nuclear energy could be used for generating of the magnetic field using electric field formation. The massive antenna could be equipped in many spots on the planet. After artificial magnetic field creations, nitrogen, oxygen and other gases could be trapped in the Martian atmosphere.

AUTHORS' CONTRIBUTIONS

The idea of the work was suggested by the authors. Modeling, implementation, calculations, writing, and revising the paper were performed through joint and equal efforts of the authors.

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АНАЛИЗА ТЕРАФОРМИСАЊА МАРСА КОРИШЋЕЊЕМ НУКЛЕАРНЕ ЕНЕРГИЈЕ У ПОЧЕТКУ КОЛОНИЗАЦИЈЕ СВЕМИРА

Као историјски изазов за људе, иницирана је колонизација Марса нуклеарном енергијом. Покретна нуклеарна електрана могла би се замислити у облику гусеничара са нуклеарним реактором. Пројектовање гусеничара нуклеарног реактора изведено је при чему је важно како оспособити гусеничар да помери реактор и његове објекте. Стога је предложена дужина клизача и контактна тачка. Нормализовани пренос топлоте анализиран је по дужини клизача и контактној тачки где су они нормализовани као 1.0 и 10.0, респективно. Иако је дужина клизача гусенице пропорционална преносу топлоте, контактна тачка показује неповољне вредности. Већа дужина клизача и мања контактна тачка могу бити оптимизовани систем генерисања топлоте од стране гусенице која је додатни извор топлоте поред самог нуклеарног реактора. Било која друга планета би се могла сматрати потенцијалоном колонијом за људе коришћењем технологије нуклеарног тераформисања.

Кључне речи: нуклеарни реактор, тераформисање, гусеничар, људска колонија