On the possibility of growing vegetables and fruits on the lunar base

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Abstract. The necessity of studying the Moon as an important source of nuclear fuel for nuclear power plants is considered. The work takes into account the geomorphological conditions of the celestial body and the basic biological needs of man. Of particular interest is the problem of fruit and vegetable production on the lunar base. This is necessary to provide the inhabitants of the lunar base with vitamins. In addition, plants convert carbon dioxide into oxygen and create an additional comfortable psychological environment. Experiments carried out in space have confirmed the possibility of growing fruit on the International Space Station (the harvest was more than 15 kg of tomatoes and 6 kg of red pepper). Taking into account the experimental results on growing vegetables on the International Space Station, a simulation of the structure of the lunar base was carried out. The strength and resistance of the structure to various influences have been calculated. Areas for planting agricultural crops have been determined, a possible harvest has been determined and the improvement of conditions for human habitation at the lunar base has been substantiated.

1 Introduction

The development of technology and the development of new horizons are an integral part of modern life. Especially in conditions of depletion of energy resources on Earth and an increase in population [1-8]. The technogenic load on the ecological system reaches its maximum [1, 3, 7, 9-16]. Therefore, projects that will solve the problem of providing the Earth's energy system with raw materials, reduce the technogenic load on the Earth's ecological system and help solve the problem of overpopulation of the planet are extremely relevant [10, 12 14-24]. One of these projects is the development of the Earth's satellite - the
Moon. In the depths of the Moon, there are large reserves of titanium and the rare for Earth isotope helium-3, which is an effective fuel for thermonuclear reactors [25-28]. It should be noted that the implementation of the project for the development of the Moon should minimize the possible damage to both the Earth and the Moon.

The peculiarity of the construction and operation of the base on the Moon is associated with large limitations of material, technical and energy resources [29-31]. Everything necessary for the construction and maintenance of the work and life of the personnel at the base is delivered by space expeditions from Earth. Therefore, it is important to use the lunar surface and lunar base facilities as efficiently as possible. For the construction of the premises of the lunar base, it is most expedient to use regolith, which constitutes the upper layer of the lunar surface. It consists of fragments of underlying crystalline rocks and fragments of minerals. Regolith has a number of undeniable advantages: it does not need to be delivered to the construction site; it has the potential to protect against radiation exposure and temperature extremes [32, 33]. This will create additional spaces to accommodate green plants. In this case, it is most expedient to place agricultural crops in the premises, which, on the one hand, ensure the processing of carbon dioxide into oxygen, on the other hand, their crops can be used to feed the inhabitants of the base. The presence of live plants at the base will create a comfortable psychological environment for the base staff.

Experiments carried out at the International Space Station and specialized laboratories at test sites, in which the conditions of outer space are simulated, have shown that the placement of plantations of pepper (red, yellow, etc.), tomato, strawberry, zucchini, pumpkin, etc. on the lunar base is of the greatest interest. This is due to the high conversion of carbon dioxide to oxygen by these plants.

Currently, many lunar base projects have been developed in the world. These projects do not provide for the placement of large areas for growing crops. In our work, this issue is given additional attention. The main problem in designing a lunar base is the construction of a protective dome over the main buildings. In the proposed project, one of the design options is presented, taking into account the placement on the basis of large areas (more than 0.5 hectares) for agricultural crops. The advantages of the presented design are lightness, convenience and ease of construction, large areas and ease of combining modules with a single space.

2 Lunar base model with vegetable stores

Taking into account the peculiarities of delivery and assembly of the base structure on the lunar surface, we have developed the following model of the lunar station blocks (fig. 1). The block consists of two parts. The first part is a Kevlar hemisphere with stiffening ribs, sheathed with a screen-vacuum heat-insulating material. The hemisphere is inflated from a module detached from the launch vehicle and landed on the lunar surface. Further, this module is used as a gateway and an entrance to the hemispherical living compartment. In part of this module, live plants can be placed, which need a temperature difference for normal development.

Between the layers of Kevlar there is a space for filling with radiation shielding material. As it inflates, the module is covered with a layer of regolith using special raking equipment [34]. This also creates protection from meteorites and temperature changes. By connecting the modules through a special design, you can get a large multifunctional sector. In this case, a large space is freed up in the modules (there should be two gateways at the base), in which green plants are placed.
Fig. 1. Base model, consisting of a Kevlar hemisphere and a module.

On the one hand, air circulation is ensured, on the other, the temperature difference and the comfort of the environment, since the personnel constantly move between the hemispheres, in which scientific equipment can also be placed.

In fig. 2, as an example, the geometry of the lunar base of 3 hemispherical domes with a diameter of 5 m each at a distance of 1 m from each other, sprinkled with regolith is shown.

Fig 2. Lunar base construction scheme.

These domes form a single connection through the modules. The required slope angle of the embankment should be no more than 22 degrees. The total length of the structure is about 33 meters, the height is about 5 m. The atmospheric pressure inside the module is set by a uniformly distributed load along the circuit and is 1 atmosphere (89.8 KPa) for comfortable human habitation. The geometry of the base is due to several reasons: with a full-fledged device on the moon, each person will need at least 20 square meters of plants inside each module to release oxygen and absorb carbon dioxide, as well as enough space for comfortable living in cramped circumstances. The space of the module with a diameter of 5 meters allows
plants and crops to be placed in the upper part of the dome, leaving space in the lower part for the astronaut to exist.

Calculation of the station structure for deformation and stability was carried out in the PLAXIS 2d software package. In fig. 3, as an example, one of the calculation examples with a maximum vertical displacement of the draft of 7.9 cm is presented, which is permissible for this design.

Fig 3. First phase of structural calculations.

Calculations have shown that the simulated base can be built on the lunar soil, will be stable and reliable. The minimum allowable height of the embankment, according to calculations, was 0.9 m. This level of the embankment is necessary to screen magnetic fields, which have much larger variations than on Earth [35, 36].

3 Placing plants on the lunar base

In fig. 4 and 5 are examples of plant placement on the lunar base under the dome of a hemisphere and along the edges of the module.

Fig 4. Tomatoes, red peppers and other vegetables in a special space module.
Fig 5. Plants for air purification under the dome of the hemisphere.

The presented variants of placement of various plants, which have been successfully tested in space, show the possibility of their effective placement on the lunar base in various modules. As a result of experiments on the space station in the module (fig. 4), 16 kg of tomatoes, 6 kg of red pepper, a large number of various greens were grown in 2 months. Measurements of the state of oxygen showed that these plants can convert carbon dioxide into oxygen, which is necessary for six astronauts. The oxygen supply is 40% of the required.

4 Conclusions

At this stage in the development of the modern world, the construction of a lunar base is one of the promising directions. Its development will expand knowledge in various scientific fields. Solve energy problems and in the future create conditions for the mass development of a new habitat.

The calculations showed that the design of the developed base is resistant to the conditions of the lunar geomorphology. The proposed design of one block can be used for 6 people. It should be noted that the reproduction of greens and vegetables in the conditions of the lunar base will create a favorable environment for work. When using a power plant with fuel (helium-3 isotope), there will be no problems with light and heat at the base. This will allow, if necessary, to allocate even more areas for green plants.

The service life of the station structure was preliminarily estimated to be over 60 years. This result requires additional verification. In some cases, solar panels can be used to generate electrical energy [37-40].

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