PRACTICAL QUESTIONS OF THE MOVING OF LUNAR SOIL MATERIALS ON THE CONDITIONS OF THE LUNAR SURFACE. *A. Kókány[1], D. Koltai[1], T. Varga[2], I. Szilágyi[2],* [1]University of Pécs, Faculty of Adult Education and Human Resourches Development, H-7633 Pécs, Szántó Kovács J. u. 1/b., Hungary (kokany@human.pte.hu). [2]VTPatent Agency, H-1111 Budapest, Bertalan L. u. 20., Hungary (info@vtpatent.hu),

Essence of our proposal: The decrease of the necessary pushing respectively pulling force due to the smaller lunar gravity is compensated by loading the lunar moving equipment with local materials. During this process the moving equipment is loaded with local lunar material so as to increase the whole mass of the moving equipment. This way the pushing, respectively pulling force ensured by the lunar moving equipment increase as well while the sticking friction remains the same.

The related physical conditions of the Lunar surface environment:

- The lunar gravity is the 1/6 of gravity on Earth.
- The mass of the materials to be moved however is the same as on Earth.

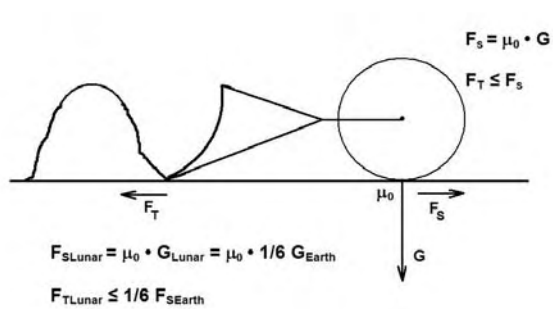

Fig. 1: The pushing force on the Lunar conditions

Due to the fact, that lunar gravity is appr. one-sixth of that of the Earth, the pushing force is also one-sixth of that of the Earth under the same surface ground-wheel connection and sticking friction.

It means, that whereas the mass of the material or soil to be moved is the same, the pushing force to be used for moving the material, which is dependent on the gravity force, - that is the dependant of the weight and the sticking friction - is only 1/6 of that of the Earth.

Issues of moving of materials on Lunar surface environment: The parameters of the material of lunar soil are basically the same as those of Earth materials of similar character e.g. bazalt on basis of the tests brought from the Moon by the Apollo programs.

During the earthmoving jobs on the lunar surface we have to work partly or wholly against the own material strength of the components of the soil, so the shearing forces to be used are the same as on the Earth. It is necessary to shear in the ground, because the layers bedded into each other, the lunar rocks must be ripped from the ground to loosen them.

Additional factors: The components of regolith are materials of different particle size with irregular surfaces, broken stone. During the moving of this type of material the particles are not kept together only by gravity, but the connection between the particles, the sticking friction resulting from the structure of the scree. Its size is not independent from gravity, because though less gravity results in less cohesive compressive force, but due to shape factors its decrease is not directly proportional with it.

It is especially important in case of 'compact soils' embedded in each other for long time, so in spite of lesser gravity, due to the temporary moonshakes as well as meteor impacts the lunar surface gets compacted to a certain extent, so the first attempt for its ripping means, that cohesive forces between soil particles must be taken into consideration. This case the decreased size of pushing force due to lesser gravity has importance as well.

During the moving of the lunar soil of loose structure, or in case of the further movement of the soil the cohesive forces between the particles do not play such an important role any longer. In case of materials of loose structure the aggregate strength is derived from the weight force, which decreases on the Moon in proportion with the weight force. This case the decrease of the pushing force does not present such a big problem when moving the set of the soil, than in case of compact materials.

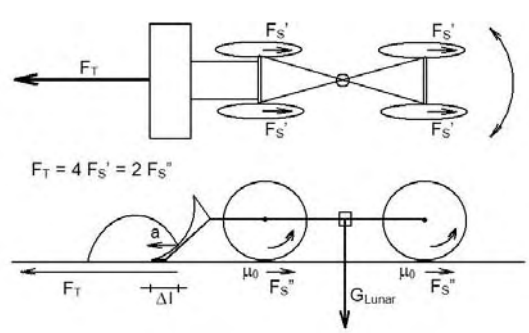

Fig. 2: Theoretical aspect of moving materials on the surface of the Moon on 'bulldozer principle'

Finding a solution: How can be proper pushing force ensured, resp. increased?

- increase of gravitational force – weight - by increasing the mass of the moving equipment,
- or by the increase of sticking friction,

A possible method of increasing of the quality of sticking the caterpillar track, or improvement of the quality of joining surfaces, e.g the ribbing. An additional increasing factor as well, that the greater weight pushes the vehicle wheel to the ground to a greater extent, this can increase to a small extent the pushing force achievable.

Possible solutions which can be applied under Lunar conditions: Vehicle provided with ballast. It is not economical, if the ballast is delivered from the Earth, because it increases the mass to be moved to the Moon unnecessarily. It has to be made from lunar material on spot.

A better solution is if the whole material or a part of it to be moved is loaded on the vehicle, so increasing the weight, which increases the pushing force at the same time.

A bulldozer e.g. provided with a blade first filling the internal storing space, then by the increased mass, which can be six-eight-ten times more than the original mass, it can carry out the moving with much better efficiency. If only five times of its own mass can be taken from the lunar soil, then the full mass will be six times more than the original was, producing the same load as if it was under Earth conditions.

The performance of the driving force does not have to be bigger, than an Earth equipment of similar size, so similar delivery and pushing performance could be achieved on the Moon as under Earth conditions.

We assume very low speed in case of pushing manoeuvres. The pushing movement itself starts from zero and takes place with very low speed.

Practical task analysis, feasibility study: Jobs are involved in a lunar moving equipment: transportation, material moving by pushing, self-loading, independent emptying.

Further conditions to be kept: least possible self weight (minimal mass), deepest possible center of gravity (stability), the simplest possible mechanical solutions, structure, the least possible energy consumption, fully automatic, robotic function,

Additional favourable functions: under-carriage, machine body should be able to be lifted, uniting of loading and pushing element, possibility of remote control, proportion of the machine body and transported useful load: 1 - min 5 or bigger.

There is contradiction among the conditions, the resolution of which is apparently impossible:

- one of the conditions is, that the weight, mass of the equipment should be the least possible,
- at the same time material moving with pushing requires the biggest possible pushing force, so the biggest possible load,

Resolution of the two aspects: loading mass should be produced from the local lunar materials, and it is obvious, that this load itself should be a useful load, a load to be forwarded, soil or other lunar material.

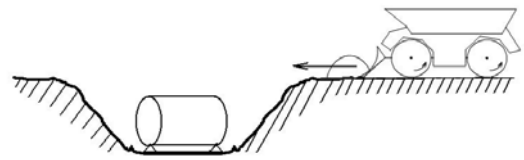

Fig. 3: Practical application of a Lunar bulldozer equipment on the surface of the Moon

Description of possible practical applications: The equipment should carry at least five-six times their own weight under lunar conditions. The center of gravity of the loading space of the structure should be as deep as possible within the inside.

First we must fill the container of the equipment with Lunar soil for the loading. After the container is filled, resp. the weight of the whole vehicle reached six times of the basic load, now it is suitable to attend pushing functions by closing the lower shovel, as the pushing force of the vehicle loaded six times equals under lunar conditions that of the pushing force of a bulldozer on Earth loaded with basic load (single). Obviously it should be taken into consideration, that the mass moved is six times more compared to the Earth, but it is important only from the point of view of accelerating or slowing down or braking the vehicle. At the same time as the load of the vehicle is useful load in given case, this is not an unfavourable condition, but a concomitant of effective use.

This way all the earthmoving jobs can be efficiently carried out with good efficiency, e.g. ground levelling, spreading, piling, deepening, forming slants.

Dumping of the material transported in the equipment on the proper place the transportation of the material to be delivered is realized, which complements the earthmoving job well, resp. increases its efficiency. It is not necessary to transport with another vehicle the material to be spread, but the same vehicle that transports it is suitable for spreading it.

Advantages: Only minimal structures must be transported from the Earth, load is ensured by local materials. It is multi-functional. The vehicle loaded can be very well used for transportation and moving.

References:

[1] Gast, P.W. et al. (1973): Preliminary Examination of the Lunar Samples. NASA SP-330, JSC; [2] Mitchell, J.K. et al, (1973): Soil mechanics. NASA SP-330, JSC; [3] McKay, D.S.; Carter,J.L.; Boles,W.W.; Allen,C.C.; Allton, J.H. (1993): JSC-1: A new lunar regolith stimulant. *24th LPSC*, Part 2. G-M p 963-964.;