PROTOTYPE OF AN EXCAVATING ROVER FOR LUNAR REGOLITH COLLECTION AND TRANSPORT

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Introduction: The excavating rover is part of the DISTOBEE system developed by SpaceTeam AGH and AGH Space Systems. It is a mobile solution designed for the excavation, transport, and beneficiation of lunar regolith to support future in-situ resource utilization (ISRU). The system was developed for the ESA/ESRIC 2nd Space Resources Challenge. The device is engineered to operate in cyclic operating mode. The platform cycle can be divided into four primary phases: transit to the excavation site, excavation, transit to the screening unit, and material discharge. The main project assumption is to collect 6 kg of lunar regolith simulant and transport into the sifter in one cycle all within 40 kg mass and 300 Wh energy limit for the DISTOBEE system.

Excavating module: Its operation is based on a screw-driven mechanism, analogous to that used in screw conveyors. The module is equipped with two parallel augers installed in tubular troughs and fitted with dedicated excavation heads. The heads excavate the near-surface layer of regolith and feed it into the tubes. The material is then transported along the tubes until they are completely filled. The tubular troughs simultaneously serve as storage chambers. Therefore, their geometry and operating parameters are critical for maximizing the mass of collected material.

Mobile platform: The excavating rover operates on a purpose-designed mobile platform. The excavation module is integrated with the platform via a pantograph linkage, which lowers the module into its operational position and raises it into a transport configuration. This mechanism ensures the required penetration depth, maintains adequate force to press the excavating heads against the surface, and provides proper alignment during transport. The platform employs a four-wheel running gear: two larger driven wheels and two smaller steerable wheels. The driven wheels feature independent actuators and a geometry optimized for fine, dust-like terrain, providing sufficient traction, precise speed control, and torque margin to overcome excavation-related resistive loads. The vehicle's travel speed is synchronized with the auger rotational speed.

Laboratory tests: A dedicated laboratory test stand filled with lunar regolith simulant was developed to optimize wheel parameters and the excavation subsystem of the excavating rover. The stand enabled adjustment of the excavating module inclination, excavating-head penetration depth, screw and excavating-head rotational speed, as well as the advance speed of the assembly. This allowed the analysis of cutting resistance, rotation–advance synchronization, and excavation performance under varying operating conditions. In addition, energy consumption and loads acting on the tilting mechanism were measured, providing the data required to optimize its final design and kinematics. The test results constituted the basis for the design of the final excavation device as one of the rover modules. The stand was also used to evaluate different drive and steerable wheel designs. Their tractive force, traction, slip characteristics, maneuverability, and integration constraints were assessed under conditions representative of field testing. During wheel tests performed without the excavation module, a controllable load was applied using a band brake mounted on the drive shaft.

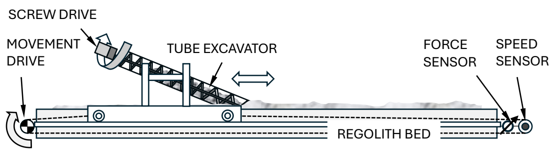

Fig.1.Diagram of laboratory test rig

Field tests: Field tests of the device were conducted at the LUNA facility. During the test campaign, the prototype operated in a stable, fault-free manner, in accordance with the adopted design assumptions. The results confirmed the high effectiveness of the proposed solution, and the achieved loading and storage performance exceeded the values assumed at the design stage. The average mass of regolith simulant collected per excavation cycle was over 7 kg, indicating efficient operation of the working subsystem and an appropriate selection of key design parameters. The report issued by the European Space Agency assessed both the device concept and its performance during the field trials were good, confirming the validity of the adopted solutions and the system's potential for further development.

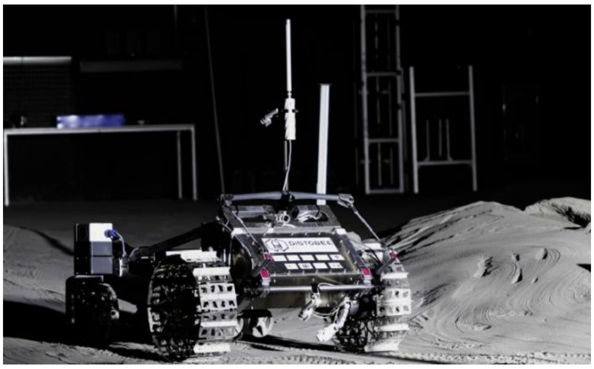

Fig.2. Lunar excavating rover in LUNA field tests