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MMD: Micro Mechanism Device

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Abstract

IPSE is a scientific autonomous micro-laboratory for Mars soil and environmental in-situ analysis. It is designed to provide the capability to serve, handle and manage scientific miniaturised instruments accommodated inside its envelope. The needing to investigate the soil in depth, in conjunction with surface and atmospheric investigation, leads to the design of a sample manipulation chain composed by a two servicing mechanism, at present under prototyping phase: a 3 D.o.F. robotic arm and a 2 D.o.F. Micro Mechanism Device (MMD). The strict constraints of the mission make necessary optimisation (in terms of mass, volume and power). Technological Evaluation Models of the subsystems have been built. Possible future developments are outlined.

1. Introduction

ASI, the Italian scientific community as well as the Italian industrial community have been deeply involved in a long term systematic program of robotic exploration of Mars together with ESA and NASA.

The collaboration with NASA was initially focused on the NASA Mars Sample Return (MSR) 2003-2005 Lander missions, with ASI providing a driller (DEEDRI) and a micro-laboratory capable of housing scientific instrumentation (hereafter called IPSE: Italian Package for Scientific Experiments). After Mars Climate Orbiter and Mars Polar Lander failures, NASA undertook a review of the whole Mars exploration program, confirming anyway its intent to pursue collaboration with ASI, with its participation in a future mission with a micro-laboratory for in-situ analyses. Italian involvement in ESA long term program Aurora make IPSE program of crucial interest in the nearest future.[1]

Starting point of the so called "Sample Transfer Chain" of Mars soil will be a drill mounted on lander or rover.

The Sample Transfer Chain (STC) performs all the IPSE operations that require movement of the samples of Martian soil collected. Samples are received outside the thermal envelope opening the STC lid, taken inside IPSE, prepared, delivered under the instruments to perform the analysis and then discharged. The STC capabilities are:

1-Receive and discharge samples. The sample is received from an external source outside IPSE envelope and then has to be discharged, outside or inside the envelope.

2-Sample preparation and calibration. The sample is pressed against a calibration rod to determine its height. This preliminary operation provides a way to evaluate correctly the proper sample position underneath the instruments for optimal focusing and, in case of dusty or soft samples, they are slightly compressed to be reduced to a proper layer.

3-Sample focusing and scanning. Bi-directional micrometric displacement of the samples allow its precise positioning on the focal plane of the instruments and analysis (for example spectrometric analysis by IRMA) with sample scanning.

The MMD mechanical structure is developed according to the stiffness to mass ratio optimisation, within the constraints of multiple environmental conditions: launch, cruise, landing and Mars atmosphere. They can be summarised as follow:

- P= 5 ¸ 10 mbar;
- Launch load: 18 g (equivalent static load);
- Wind speed= up to 20 m/s;
- Sand-storm wind speed up to 100 m/s.

MMD solution concerns, to satisfy fine positioning in a so wide temperature range, particular attention is put in thermo-elasticity analyses and thermo-structural design and in the selection of discrete components like actuators, ball bearing, lead screws. The selection of materials is a key feature for MMD in order to fulfil the requirements within the allocated resources. The sub-unit are conceived single-pointfailure tolerant and fail-safe proof.[2]

2. Contents

The Micro Mechanism Device (MMD) is designed to perform micro positioning of soil samples under payloads according the following specifications:

- to move the soil sample under payload for focusing porpoise with an accuracy of 50 µm for a total travel of about 0.5 mm;
- to move the sample for scanning porpoise with an accuracy of 5 µm and a total travel of about 10 mm.

This capability is very important because it provides a powerful tool both in terms of servicing and flexibility: i.e. an optical instrument without any focusing device can be used properly for a wider temperature range thanks to MMD capablity. Moreover scanning with high accuracy can provide capability to obtain two dimensional information and detailed observation of the sample. The mechanism has to survive during the lunch phase, the cruise and the analysis of about 10 samples. The mass budget for the overall mechanism is 200 grams that is satisfied using Aluminium alloy as structural material for the mechanism.

The design has began with the conceptual design of the mechanism in order to decide the best initial solution that ensure the functionality of the device. This technique starts with the generation of several concepts and ends, after refinements and exclusions, whit a single concept to develop in a project. The successive step has been to translate the concepts in a design of the device. To perform this, stress has been put on the easiness of assembly and limitation of encumbrance and mass.

To reduce the risk of failure during the scientific operation, it has been decided to minimise the amount of parts in mutual movement to each other, substituting rolling devices (like bearings or rolling leadscrew) with slave devices. To reach comparable coefficient of friction whit rolling devices, Vespel has been chosen as friction material, taking into account its low density, good mechanical characteristics compared to other plastic materials, very low out-gassing. A technical explanation of the mechanism leads to split the entire device in two subsystems: the vertical motion system and the horizontal motion one, where the horizontal plane is assumed to be the focal plane. The motion in the vertical direction is achieved by the use of a slide, joined to the horizontal plane between inclined planes. The slide run on Vespel™ sliding block and the actuator is a stepper motor, with a 11.8:1 gearbox, joined to a lead-screw (fig. 1).

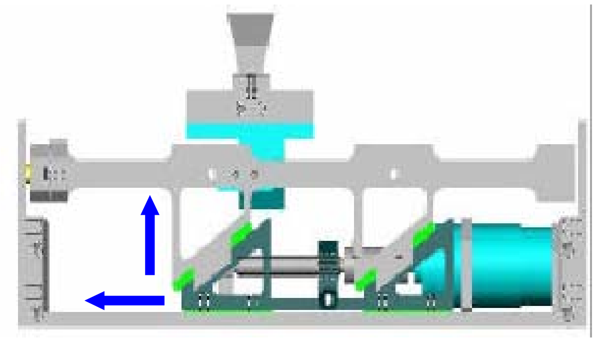

Fig.1: Vertical plane movement system

This device allows vertical excursion according to the requirements, with the advantage to be compact (the mechanical chain is directly inside the system).

The motion in the horizontal plane is achieved by means of a lead-screw joined to the sampletrolley. The screw is made in aluminium alloy and the nut in Vespel™ SP22 which shows best wear and frictional characteristic even in contact with relative soft material like aluminium. The nut has an anti backlash system for the compensation of the clearance generated by the wear under function (fig. 2).

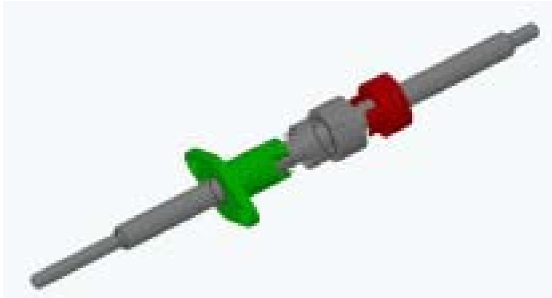

Fig. 2: Horizontal plane motion system.

A stepper motor with a 76:1 gearbox (fig. 3) achieves the motion of the leadscreew.

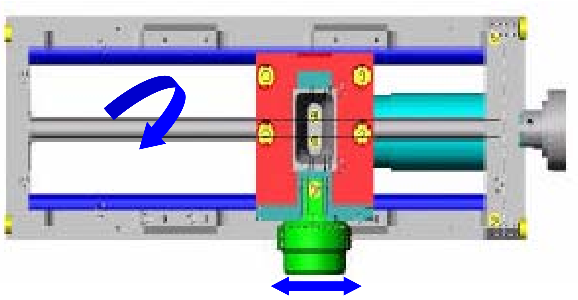

Fig. 3: Horizontal plane motion system.

As shown in figure 3, the motor is in the bottom side minimising the room while the motion is transferred to the screw by means of anti-backlash gear system. The sample-trolly runs on two stainless-steal rods by means of a pair of V sliding-block. The geometry and the choice of the materials in contact (Vespel™ SP3 against stainless steel) ensure a certain amount of preload even if differential thermal expansion occurs during the operative life of the mechanism.

As baseline, the sample container is detachable from the mechanism, so that the entire container for each sample can be changed, preventing cross contamination (see fig.4). The attachment system has a bayonet joint for interface with the manipulator and a preloaded device that ensure repeatability and accuracy in sample motion.

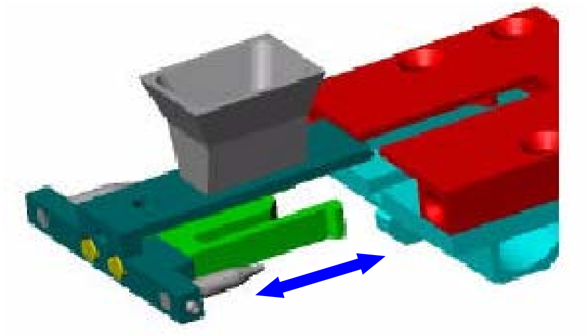

Fig. 4: Sample container system

With the actual design MMD could perform:

- a minimal horizontal motion increment 0.44 µm
- a minimal vertical motion increment 1.63 µm
- power ≤ 0.3W (for each motor)
- minimum operational temperature –80 °C

Technological Evaluation Models of IPSE most challenging subsystems have been built. These are:

- STC Robotic Arm TEM
- STC Micro Movement Device TEM

The robotic arm and MMD TEMs, have been built to demonstrate the feasibility of the two subsystems in terms of the capacity to abtain the necessary accuracy, structural stiffness and reliability with the strict mass budgets assigned for the mission. The following figure shows the two subsystems during a demonstration of the STC operation (fig.5).

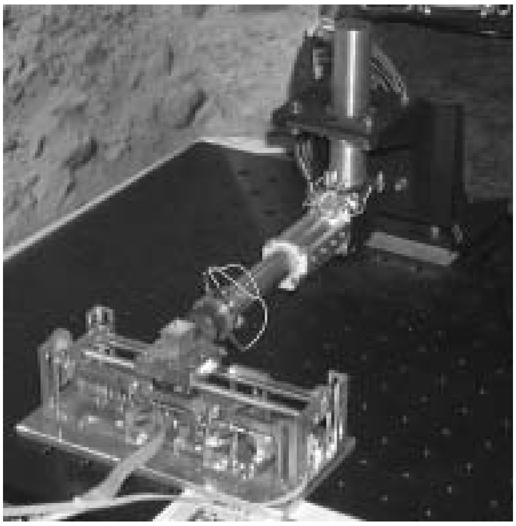

Fig. 4: Sample Transfer Chain

3. Conclusion

The prototype of the mechanism is under study to test its funtionality. Base interferometer misurements in one direction is in progress, as show in the picture below (fig. 6), to demostrate that the horizontal plane has the necessary precision and accuracy.

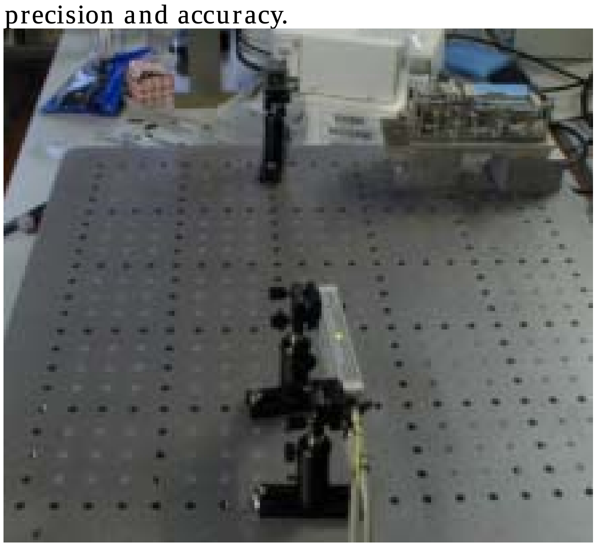

Fig. 6: Interferometer system setup

In order to minimize the encumbrance of the sustem it's under study a new relase of the mechanism. In this new design it's also made an effort to improve the horizontal motion system, in order to have in contact conforming (rolling) surface instead of non conforming (sliding) ones.

In the picture below is shown the conceptual model of the new MMD (fig. 7).

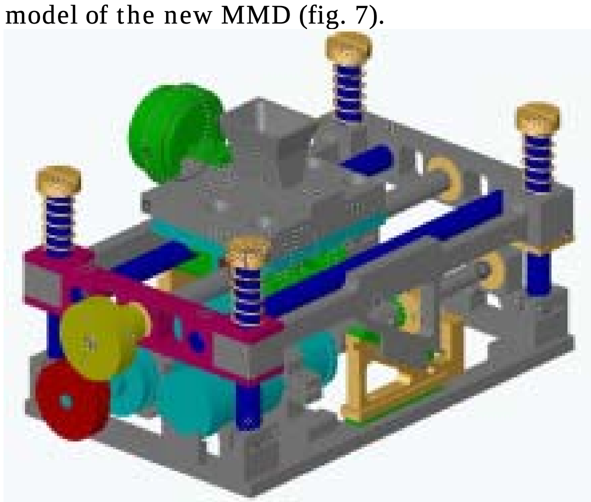

Fig. 7: New MMD conceptual model

Reference

[1] F. Angrilli, S. Debei, F. Rossi, E. De Marchi, R. Ferrario, W. Prendin, T. Terribile, S. Espinasse, E. Flamini, "IPSE The Italian Package for Scientific Experiments on Mars", Explorin Mars Surface and its Earth Analogues, Sicily and Mount Etna, 23-25 September 2002.

[2] S. Debei°, F. Angrilli°, F. Rossi°, R. Mugnuolo+, M. Marchesi°, R. Ferrario°, "Sample Manipulation with Robotic Arm for planetary exploration".