Focusing System Flexure-Mechanism for the Close-Up Imager Instrument of the ExoMars Rover

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Abstract

This paper presents the design of a flexure based focusing system, part of the Close-Up Imager (CLUPI) instrument which is planned to be integrated on the future ExoMars NASA-ESA Mars Rover to be launched in 2018. Various design trade-offs are discussed, in particular the selection between a non-symmetric isostatic kinematic flexure arrangement and a symmetric but over-constrained arrangement. The selected solution is based on an original architecture consisting of three identical EDMmachined compliant plates connecting the mobile lens assembly to the fixed outer frame. This novel technical solution has potential use for all kinds of focusing mechanisms dedicated to harsh environments.

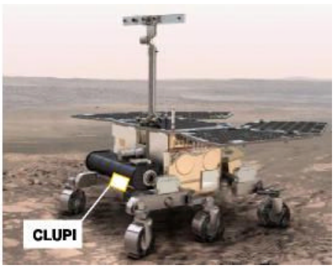

Figure 1: View of ESA's ExoMars Rover (souce: ESA)

1 Context of the development

The CLUPI instrument is planned to be mounted on a Rover drill for an exploration mission of planet Mars dedicated to exobiology and geochemistry research[1]. CLUPI will act as a robotic substitute to a hand lens, one of the most useful instruments of the geologist field; high resolution imaging of rocks surfaces, soils and wind drift deposits will indeed provide key information to help understanding the geological context of the sites explored by the Mars Rover. The specific function of the Focusing System (FS) presented in this paper is to vary the focal point of the CLUPI instrument by moving a set of lenses along the optical axis.

2 Main challenges of the design

The focusing mechanism must comply with the following key specifications:

- CLUPI working distance ranges from 10 cm to infinity which requires moving the lens assembly in a rectilinear translation over 10 mm with a high position accuracy of 20 μm and small lateral deviations that must remain below 50 μm.
- The mechanism total length is only 100 mm, as compared to the required stroke of 10 mm, and the maximum acceptable outer diameter is 50 mm; the resulting volume is therefore small for the integration of an actuator, a sensor and a precise guiding mechanism over a long stroke (10 mm / 100 mm).
- Stiffness: the second eigenmode must be above 160Hz (the first mode corresponds to the natural axial motion required for the focusing function)
- The focusing mechanism must generate no particles that could harm the optics.
- Large range of working temperatures: from -120°C to +30°C.
- The mechanism will be in direct contact with the Mars atmosphere (6 mBar, 95% CO_2) and should withstand sandstorms and any fine particles that might get through the protective cover.
- The mechanism must withstand launch vibrations without an additional device to block the mobile stage.

The required focusing system must therefore be specifically optimized for long stroke, very low mass, small diameter and high stiffness.

3 Design approach and selected solution

The rectilinear translation guiding concepts for a 10 mm stroke in a small volume could be grouped into two categories:

- Classical bearings concepts:
  - Contact-based bearings: while bushings exhibit friction, ball bearings require lubrication to decrease it; both generate particles and therefore need to be hermetically sealed to avoid contaminating the optics.

  - Contactless bearings: magnetic bearings require continuous power.

- Flexure-based bearing concepts:
  - Compliant mechanisms are technologically simple, they are not sensitive to dust, do not generate particles and do not require power. The latter (flexure-based bearing concept) has been selected for the guiding stage of the focusing system.

Figure 2: double membrane rectilinear flexure-bearing

The selection of the rectilinear-flexure design has been done between a double membrane rectilinear bearing (Figure 2), a non-symmetric isostatic kinematic flexure arrangement comprising five arms (Figure 3, right) and a symmetric but over-constrained arrangement comprising six arms (Figure 3, centre).

The first concept (double membrane) has been abandoned because the proper integration of a voice coil actuator would have required a specific development and a costly space qualification process. While the second concept (isostatic arrangement) is conceptually appealing, its second eigen frenquency was below the targeted 160Hz and increasing it would have required a complex and specific design of the frame comprising a single arm on one of the three plates. The third concept (symmetric arrangement) could easily be optimized in order to reach a second eigenmode above 190Hz. It has therefore been selected. The over-constraint is coped with by using relatively thin plates and by using precision shims to guarantee that no stresses are induced into the structure during the assembly process.

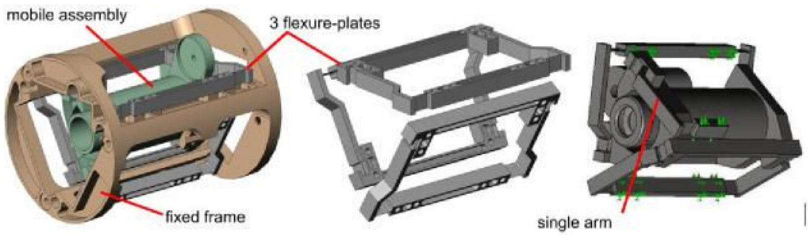

Figure 3: FS Flexure-Mechanism: six arms symmetric arrangement (left & middle) and five arms isostatic arrangement (right)

To actuate the mechanism, several actuators have been considered:

- Piezo stick&slip actuators: they are low power, power-off stable and backlash free but generate particles and require high voltages (100's volts)
- Linear actuators made of the combination of a linear screw and a rotary motor: they can comprise integrated encoders, they are generally lower power and power-off stable, but they exhibit backlash and friction.
- Voice-coil actuators: are contactless, frictionless and do not exhibit backlash.

Due to all its advantages, a commercial voice-coil actuator has been chosen. To measure the guiding stage position, an LVDT sensor has been selected due to its space heritage, its small size, its contactless working principle and its compatibility with the operating temperature range.

4 Conclusion and outlook

The selected solution is based on an original architecture consisting of three identical EDM-machined compliant plates connecting the mobile lens assembly to the fixed outer frame. This novel technical solution has potential uses for all kinds of focusing mechanisms dedicated to harsh environments and represents a novel application of flexures for high precision space applications.

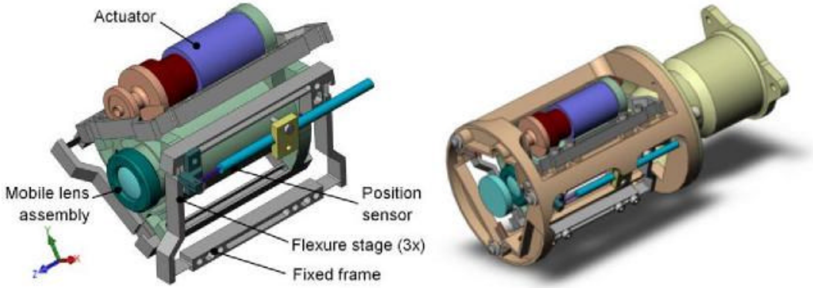

Figure 4: left: inside of FS Flexure-Mechanism, right: CLUPI focusing mechanism

Acknowledgments:

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References:

[1] exploration.esa.int/science-e/www/object/index.cfm?fobjectid=47068