Assessment of Precision Force Actuators and Non-contact Force Sensors for Astronomical and Medical Applications

S. Droz, W. Glettig, C. Hennemann, I. Kjelberg, H. Saudan, L. Voruz

In the frame of an internal research project, two demonstrators were conceived, manufactured, assembled, and tested: one for a simple, passive force sensor with non-contact read-out, for a potential medical application; another one to assess the true limits of resolution of a commercial motor-gear-spindle drive in a force actuation principle arrangement for typical Adaptive Optics application. For the latter, the demonstrator was assembled and tested within a Bachelor work at the HEIG-VD (Yverdon-les Bains) under the supervision of Professor Michel Girardin.

Non-contact read-out, simple, force sensor

Monitoring forces in a structure, or in an implant by simple means, remain a challenge. The sensor shall be simple, and passive, maintenance free, and require no power, etc.

How to simply interrogate, at distance, the tension of a spring force device, and the force evolution over time?

The response proposed is to use the spring coil structure as an inductance, add a two plate capacitor structure and thereafter analyze the electric resonance frequency, or complex impedance and associated changes, to correlate to the spring tension. A calibration of the system, before embedding, is required. The proposed principle applies to all pretension type force application devices, where a filament or wire is under pretension by a compressed spring.

At first, Finite Elements simulations were performed, on typical small (1cm^3) structures comprising a compression spring and a surrounding mechanical support acting also as a passive plate capacitance. The design was further enhanced by adding a supplemental coil to further increase the mechanical spring's low inductance. This increases the complexity of the solution but enhances the frequency domain resolution of the complex impedance measurement.

Typical force range is 0-100 N (adaptable by a spring stiffness change) and resonant frequency range of 6-12 MHz for such a sensor. Measurements show good concordance with performed simulations, as presented hereafter for the copper coil version under Figure 2 below.

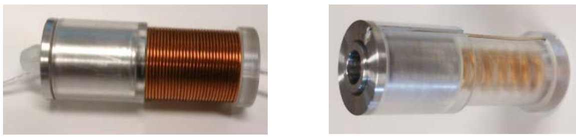

Figure 1: With and without copper wire coil (diameter 12 mm).

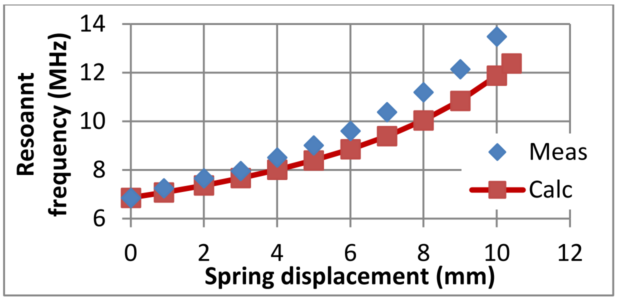

Figure 2: Typical response curve for copper coil version.

The feasibility is shown, allowing non-contact force measurements. It remains: to simplify the design and possibly pass into the GHz frequency domain.

Force actuator for adaptive optics

Adaptive optics is a way to improve the nanometric precision control of optical surfaces of mirrors and lenses, when these are deformed by thermal and gravity loads, i.e. in a telescope, or for space and satellite optics. One way, shown by astronomers at the Marseille Astrophysics Laboratory (LAM), is to attach a dozen of linear force actuators to a mirror structure. Switzerland has the most advanced miniature motor manufacturer proposing complete motors-gear-spindle position actuator arrangements.

How to best transform such a stiff position actuator into a compact force actuation systems and which force range and resolutions can one expect from existing industrial devices?

CSEM selected a system from maxon motor® EC/GP16, designed a simple flexure assembly to transform the position actuator into a force actuation scheme, and added a dummy representative membrane load. The test bed assembly with motor control and force range, and assessment of resolution and backlash was performed in the frame of a Bachelor work at HEIG-VD. The measurement results show a high linearity and resolutions (see under Figure 4). This series elastic force actuator transfers efficiently up to 25N force or some 6um displacement to the structure, with potentially nm resolutions, on a 4 N/um stiffness.

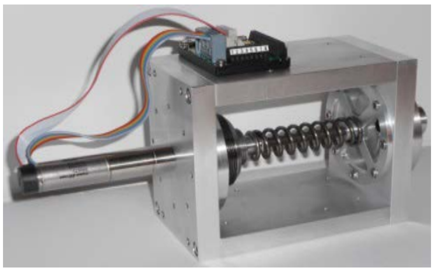

Figure 3: Force actuator test set-up based on a EC/GP16.

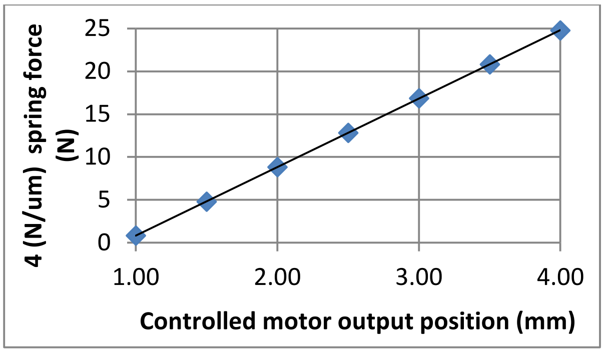

Figure 4: Spindle displacement versus mirror force and displacement.

This work was partly financed by the Canton of Neuchâtel and CSEM would like to acknowledge and thank for this support.