Design and construction of an apparatus for testing sand contacts between silica sand grains

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1. Design and construction of an apparatus for testing contact resistance between sand grains

There are no standard or commercially available devices capable of measuring the response of contacts between sand grains to loading. The project requires a capability of measuring the resistance of inter-grain contacts, subjected to different sustained loads prior to reaching contact yielding. The purpose of this description is not to show all the details of the apparatus design; rather, it is to report on the progress of design and construction in the first year of the project funding. A conceptual schematic is illustrated in Fig. 1.

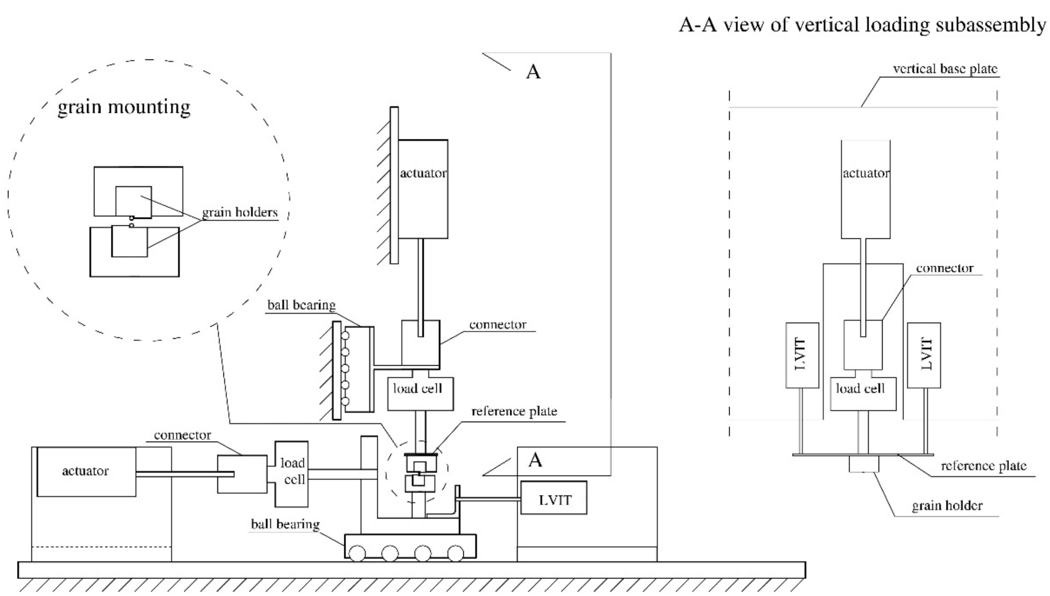

Figure 1. Conceptual design

The size of the base of the apparatus is 30 × 60 cm. The fundamental components of the apparatus are two actuators, each with one degree of freedom, attached to the upper and lower grain holders. The actuators are connected to the grain holders through load cells, which will measure normal (vertical) and shear force (horizontal) applied to the nominal contact. The system will allow for loading programs with sustained load prior to shearing, variable and time-dependent loading, or cyclic loads.

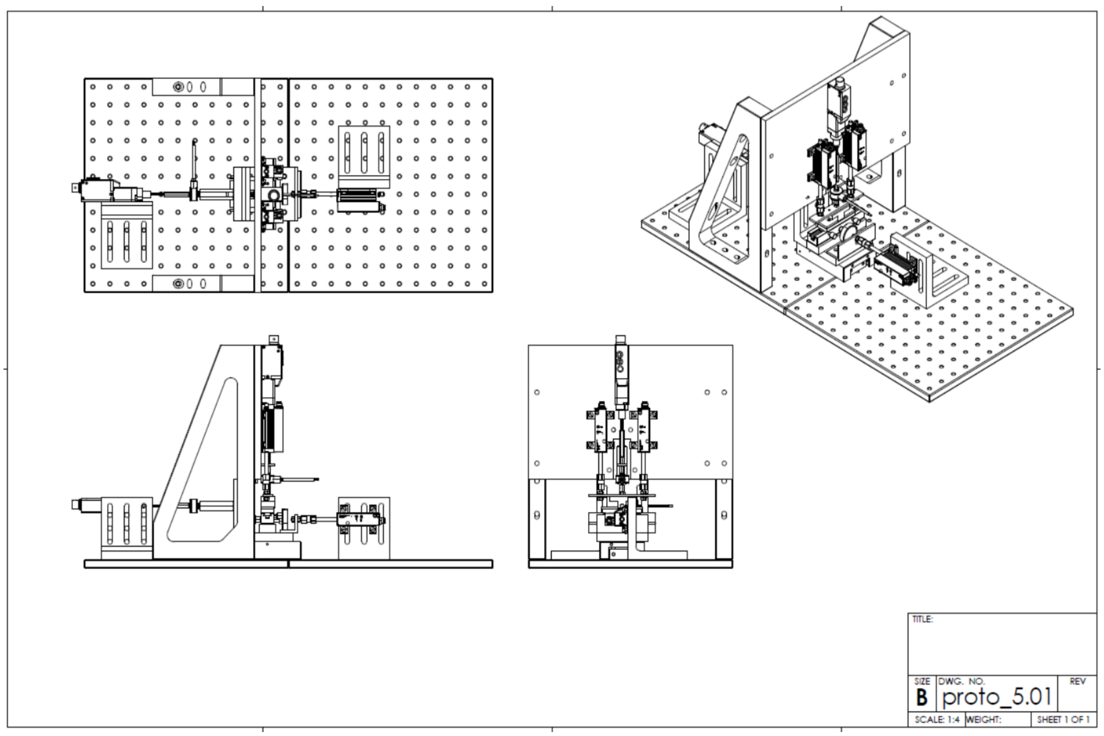

Figure 2. Different views of the apparatus design

Different views of the designed apparatus are illustrated in Fig. 2 on design drawings, and the screenshot of the design is shown in Fig. 3.

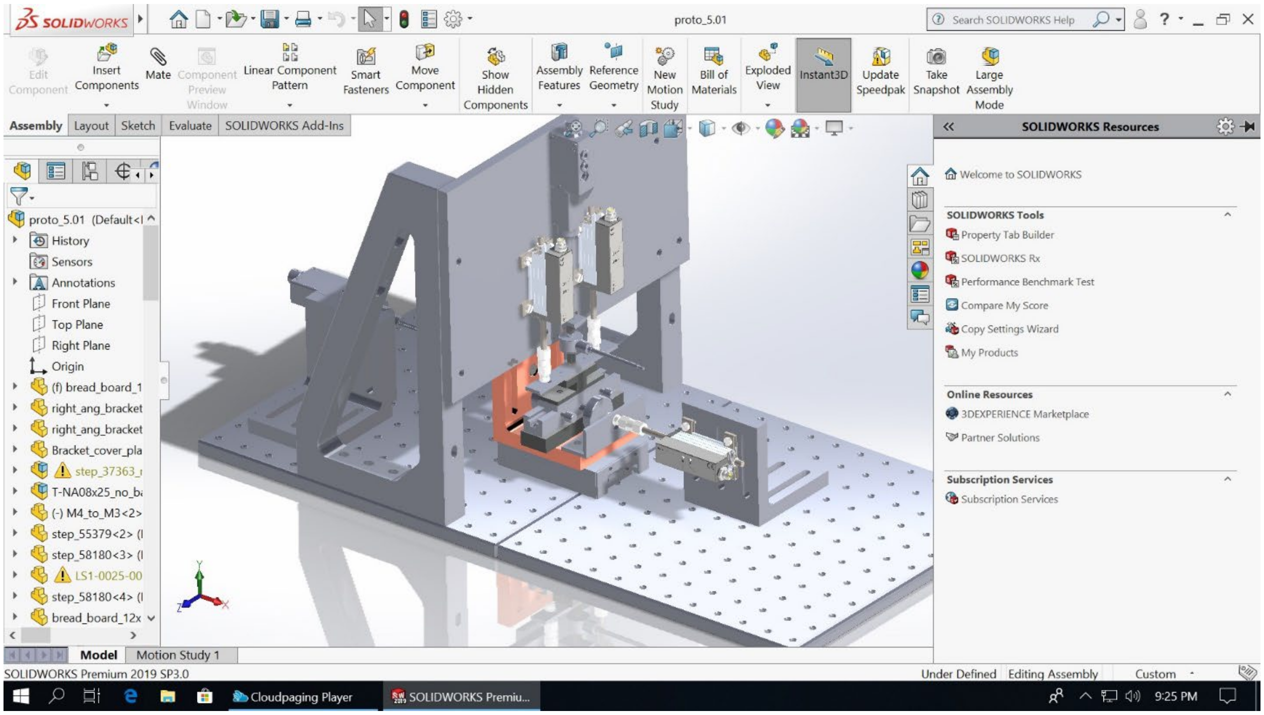

Figure 3. Screenshot of the design

Two views of the apparatus under construction are shown in the photographs in Fig. 4.

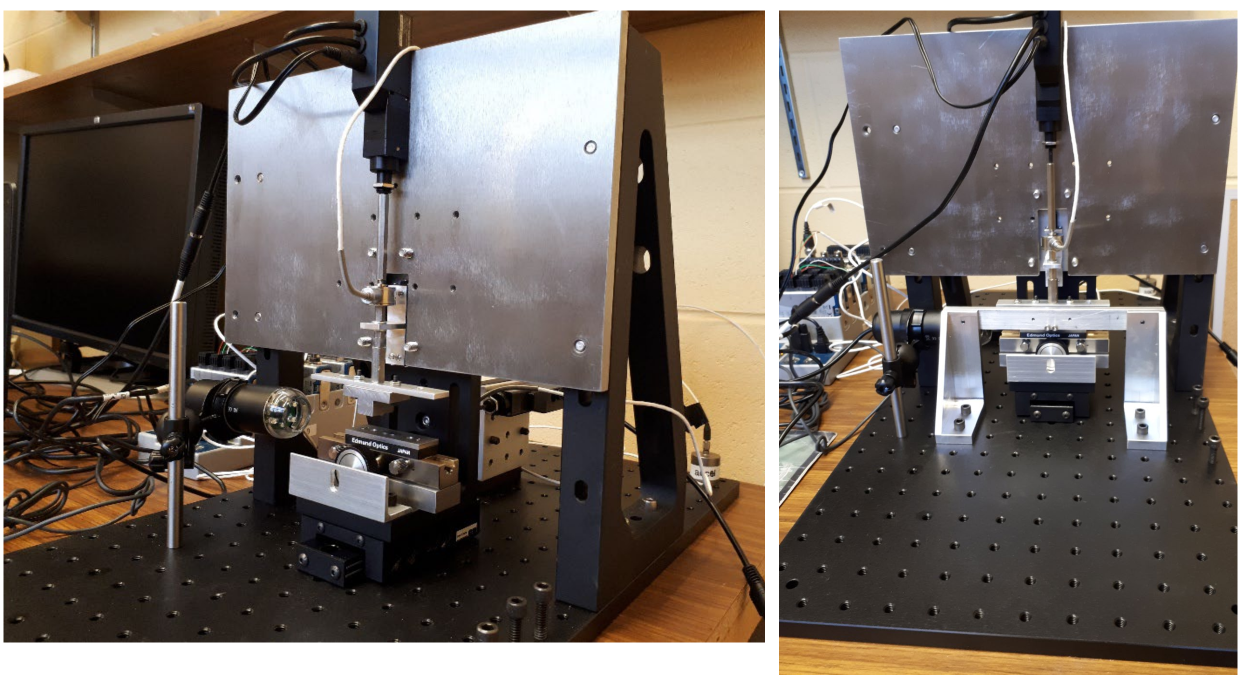

Figure 4. Views of the apparatus under construction

1. Choice of sensors and accuracy of measurements

Current work is concentrating on the choice of the sensors to be used, based on the accuracy and robustness. Comparison of sensors accuracy is illustrated in the following example.

An accuracy of displacement sensors was tested with a focus on linearity and noise. A potentiometer and a Linear Variable Inductive Transducer (LVIT) were aligned with the actuator rod. Voltage readings from sensors were acquired using National Instruments data acquisition system. An optical microscope was focused on the head of the actuator rod. The setup of the sensors is presented in the Fig. 5.

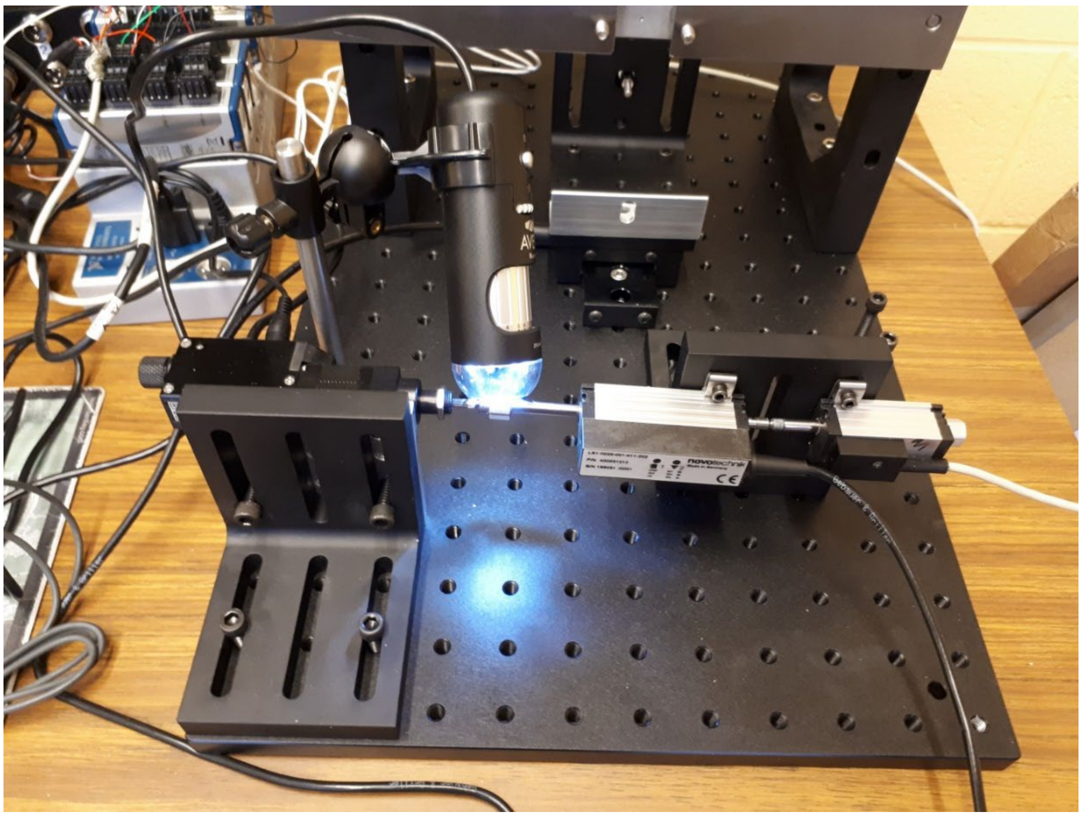

Figure 5. Setup of sensors for testing linearity and noise

A 110-μm displacement was induced in eleven 10-μm increments during the test. After each increment, sensor readings were acquired for 10 s with frequency of 10 Hz. Furthermore, after each step three image frames were captured by the digital microscope shown in Fig. 5. Displacements of the actuator rod were calculated using video analysis with OpenCV library in Python environment. The comparison of the displacement sensors noise is visualized in Fig. 2.

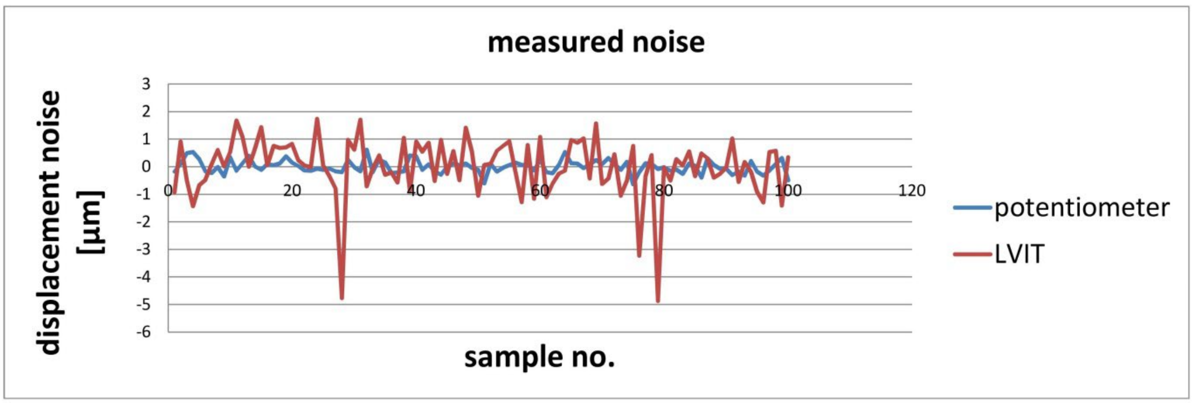

Figure 6. Comparison of noise in the displacement measured by the potentiometer and the LVIT

It appears that the noise produced in the LVDT sensor substantially exceeds that in the potentiometer. The results are presented in terms of displacement (in μm).

Linearity results of all three methods used for measuring displacements are presented next. Figure 7 illustrates the applied displacement versus average displacement calculated after each step using the potentiometer, LVIT and the digital microscope readings.

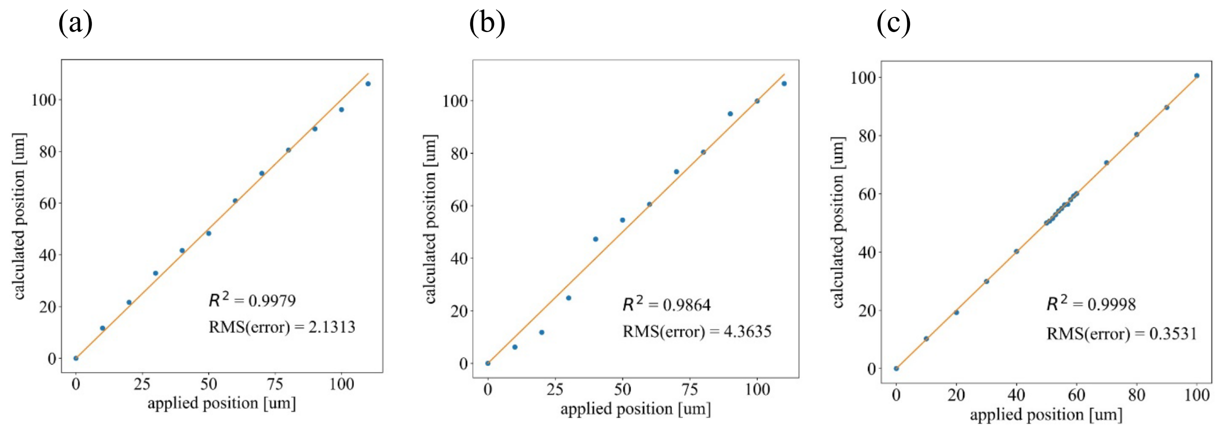

Figure 7. Linearity tests for three methods of displacement measurement: (a) potentiometer, (b) LVIT, and (c) optical method (digital microscope)

Potentiometer measurements are significantly more accurate than the LVIT's. The most accurate method for measuring displacements is the optical method utilizing digital microscope. In addition, this method has an advantage of contactless measurement. However, its limitation is low sampling frequency.

Summary

This file describes advancement of work on the design and construction of a new apparatus for testing resistance of contacts between sand grains.