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DESIGN AND DEVELOPMENT OF A SYSTEM FOR LAYER DEPOSITION IN AN AUTOMATED DEVICE FOR THE SIMULATION OF GEOLOGICAL STRUCTURES

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ABSTRACT
The simulation of geological structures consists in a controlled construction of natural scaled models of structures from the surface of the earth, such as faults and basins. The models of study are formed of samples layers of different sizes, from 300x1000mm to 1000x1000mm, made of clay, sand and silicone. The distribution and dimensions of the layers results of vital importance to represent the real behaviour of the natural structures.
The preparation of the models and of each layer is a slow and fragile process since each layer is deposited on top of the previous one materializing a very complex structure. With these requirements, the present paper presents the design and development of an automated device for layer deposition and specific sand recoating that allows controlling the volume of sand that pours within each sample. The system is controlled through electrical motor and the project has embraced the initial design of manufacturing, assembly and the set up of the system.
Keywords: Additive deposition, Geology, Modeling, Design, Prototype

1. INTRODUCCIÓN
Analogical geological modeling consists in the reproduction of scaled geological structures with the objective of understanding its evolution [1, 2]. The models represent geological structures made in several dimensions, in the spatial or temporal scales, and with different materials. If the models are right scaled its evolution can be compare to its natural equivalents [1].
The materials used in these models are quartz sand, clay, glass microspheres and silicon. These materials behave just as its natural counter parts given the modeling conditions, especially if they are distributed in consistent layers. The height of each layer varies between 1 and 10mm. One of the main properties of the materials used is the cohesion rate, since it is that property that gives more or less resistance and friction to the model. Mainly the models are quadrangular geometrical variations where colored layers of the different materials are built.

2. SYSTEM REQUIREMENTS AND DESIGN PRINCIPLES
There are several aspects related with the distribution of the layers that can invalidate a model. In this article we will mention those related with the layer preparation:

The requirements are:

- The layers should not be compacted.
- The layers' height dimensional tolerance should not exceed +/-0,25 mm.
- The flatness between layers should not exceed +/-0,5 mm.
- The distribution should be uniform to avoid undesired nucleation points.
- The projection height should be minimal.
- The inferior layers shall not be altered.
- The model should not me moved while the layers are formed.

Once the initial requirements were determined, the following design principles were defined for the device:

- It must incorporate a material buffer that can move along the model.
- The material buffer should have the capacity of material enough to build the highest layer without needing a refill.
- The device should lay the material during the translation (continuous layering deposition).
- The device should be able to generate layers between 1 and 10mm of height.

3. CONCEPTUAL DESIGN

As conceptual design an opposite roller system was proposed. The solution suggested was composed of a material buffer with to cylinders capable to roll in opposite directions, moving the material in contact with the upper surface towards its lower part. To control the flux of material carried by the rollers, the cylinders are separated from each other. With this procedure a constant flux of material is achieved, generating a homogenous layer in the model.

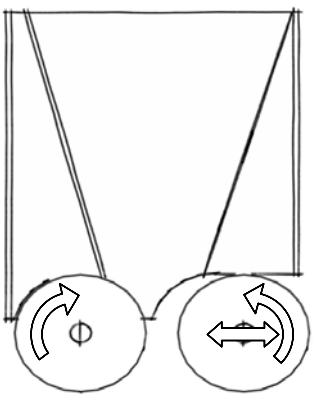

Figure 1. Opposite Roller System

Once the material deposition was successfully addressed, the next issue was to achieve a continuous material deposition over the whole model. The solution proposed was to connect both movements, the rotation of the rollers and the translation of the device. For this purpose, a couple of translation wheels are added. The wheels have an inverter to maintain the direction of the material rollers.

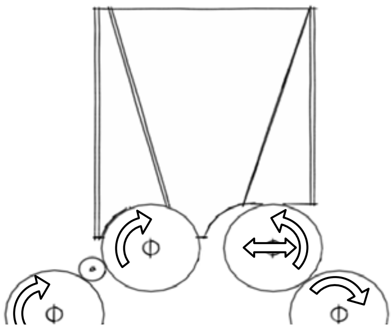

Figure 2. System with translating wheels

There are several uncovered requirements in this initial conceptual design such as the behavior while applying different materials, the possibility to lay different thicknesses or the difficulties for the mechanical integration with the rest of the device, among others.

After developing drafts of the concept, it was decided to manufacture a prototype to validate the idea, prove and discover more attributes of the conceptual design.

4. PROTOTYPE

Once the conceptual design was built some changes to the original design were made. The prototype was built with 4 axes, 2 for the translation system and 2 for the material rollers.

One of the translation axes is equipped with friction wheels that at the same time activate the rollers.

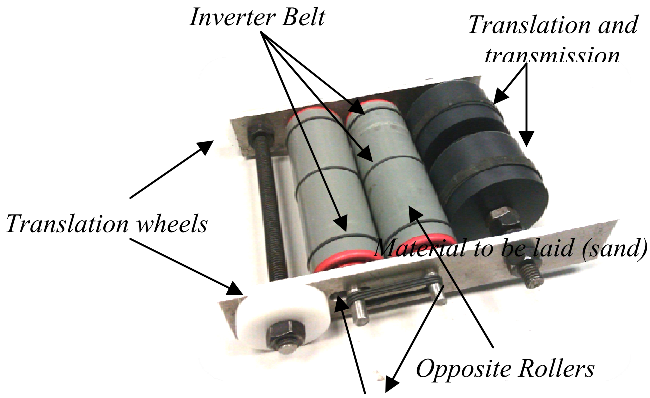

Figure 3. Prototype with 4 axes

To achieve the opposite movement of the rollers, the system has 3 timing belts that invert the spinning movement.

To validate the flux of material, slots are made in the support of the second roller. This allows varying the distance between the rollers and increasing or reducing the quantity of material processed.

On top of the device touching the rollers a deposit of material was placed.

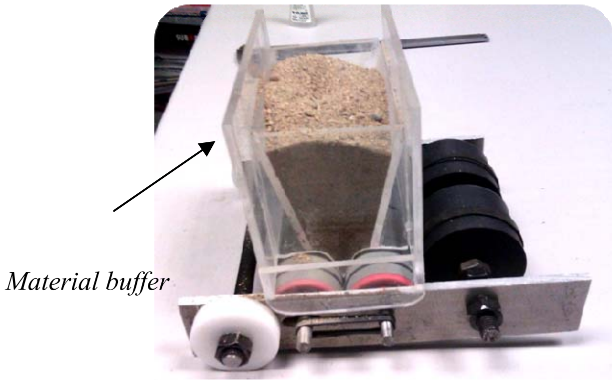

Figure 4. Prototype with the material deposit.

The tests are done with 3 kinds of materials: quartz microspheres (maximum grain size 50 µm) and clay.

5. VALIDATION TESTS

Testing the device we could observe some valid and invalid issues:

Figure 5. Results of one of the first test

The performance of the device was mechanically correct; and the binding of the movements useful for the desired behavior. The layer formed was homogeneous both in height and distribution.

During the tests, the different materials gave irregular results. The influence of the properties of the materials showed to be determinant on the test results. The humidity has strong influence in the cohesion degree and this is determinant in the transition to the rollers. If the material is excessively compacted, the rollers spin alones and do not have the capacity to move the grains. On the contrary if the materials are too dry, they flow without control through any slot and its behavior is unpredictable. There are also irregularities at the beginning and at the end of the deposition trajectory. When the material should go through the rollers and deposit over the model for the first time the result is irregular. When the deposit of the material is emptying, the grains tend to accumulate on the sides making the flow of material irregular.

6. FINAL DESIGN

With the experience obtained from the tests and the prototype another alternative was proposed. The new concept kept the material buffer and the rotation-translation relationship, but one of the rollers was eliminated. Instead a striated roller was located inside the material buffer where the axis helped to lead the material to the depositions slot. A prototype of this axis was developed to test the functionality.

The synchronization was solved motorizing the roller axis and transmitting the movement trough a clutch with gears that rolls over a rack and pinion over the rail of machine.

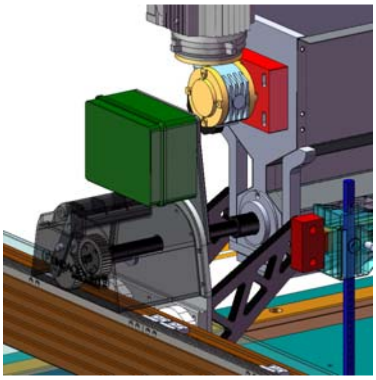

Figure 6. Transmission

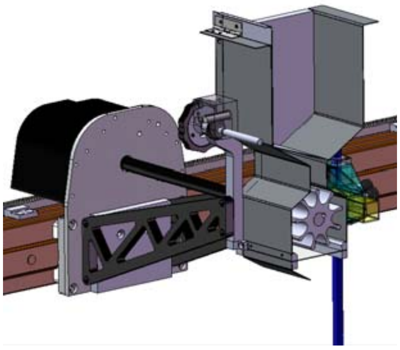

Figure 7. Axis partial view

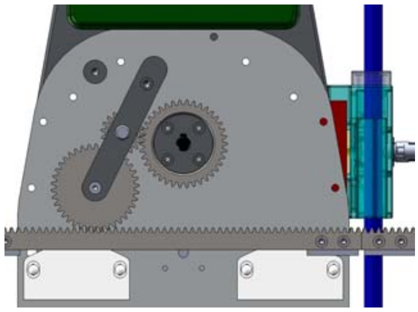

Figure 8. Gear details

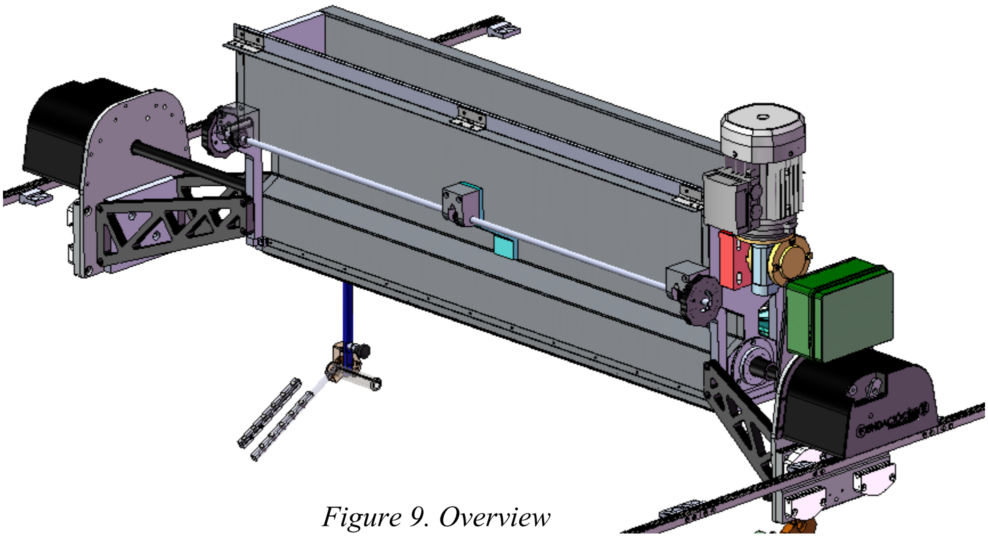

Figure 9. Overview

7. CONCLUSIONS

The physical development of the prototype has been of big importance in order to ease the final development and integration in the complete analogical modeling system, as many factors could not be easily tested directly from the CAD design. The prototype built for this paper contributed enormously for the manufacturing of the geological modeling system that now is performing geological experiments. The resulting equipment is unique and has been ranking best in class because is capable of integrating the main geological modeling testing types, such as strike-slick and double wedge and the different most used materials for modeling such as silicone, clay and sand.

8. REFERENCES

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