Modeling and simulation of a linear motor in a liquid-frozen deposition system for additive manufacturing.

M. Silvestri*,†, H. Giberti※

* Department of Engineering and Architecture
University of Parma
Parco Area delle Scienze 181/A, 43124 Parma, Italy
e-mail: marco.silvestri2@unipr.it, web page: http://silvestri.rocks

† Department of Innovative Technologies
University of Applied Sciences and Arts of Southern Switzerland (SUPSI)
Via Cantonale 2C, 6928 Manno, Switzerland
Email: marco.silvestri@supsi.ch

※ Department of Electrical, Computer and Biomedical Engineering
University of Pavia
Via A. Ferrata 5, 27100 Pavia, Italy
Email: hermes.giberti@unipv.it

ABSTRACT

Additive manufacturing technologies are expanding their field of application in an ever increasing number of industrial sectors through the development of new processes, the use of new materials and, by consequence, the design of new machines. In the medical devices industry, the augmented demand for devices devoted to tissue regeneration based on a controlled micro-architecture in recent years led the interest for industrial scale-up in the production of hydrogel-based mass-customized manufacts. The present work is related to the fabrication of a scaffold with a customized shape through a variant of an additive manufacturing process that in the literature has been proposed by different names such as low temperature manufacturing (LTM), liquid frozen deposition manufacturing, cryogenic prototyping and rapid freeze prototyping. This process can be successfully carried out by controlling a set of parameters that includes the role of the viscosity of the starting hydrogel solution and the effect of temperature and speed on the success of frozen deposition.

The LTM system presented here constitutes the evolution of a first prototype presented in the past [1] and allows improved features and performances (precision, print speed, work envelope) through two fundamental design choices: firstly, the adoption of a thermal chamber to control humidity and temperature of the work envelope; secondly, the use of a XY-stage actuated by high precision linear motors of reduced dimensions. As a consequence, linear motors operation at low temperature (-15°C) constitutes a technological challenge because of the temperature influence on the electromagnetic phenomena underlying linear motor working principle. In fact, such temperature makes the behaviour of the system substantially different from what occurs at environmental conditions and requires a complete overhaul of the control system.

In order to better understand the incidence of these phenomena and to develop an appropriate control algorithm, a multi-physics simulation was developed in Open Modelica environment. It reproduces with great accuracy the functioning of a linear motor and the consequent behaviour of the system on varying the operating temperature, taking into account the influence of the temperature on the solenoid intensity, the voltage, the exerted forces, the velocity and the position (5% less of accuracy). The results obtained confirm that, at the temperatures considered, the motor positioning error is significant and undermines the correct operation of the controller. On the basis of the values found, the correct control system is currently under development.

REFERENCES

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