HSLU Hochschule Luzern

Technik & Architektur

**Master Thesis, Mechatronics and Automation**

# Realisation and optimisation of the incubation system of a novel bioreactor for the simulation of intervertebral disc loading in weightlessness.

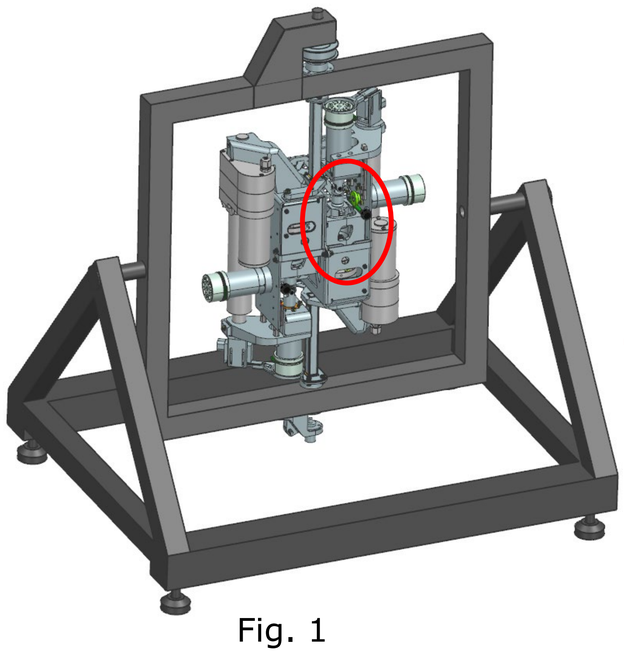

Fig. 1

IVD bioreactor Gen2 mounted on a microgravity simulator (black).

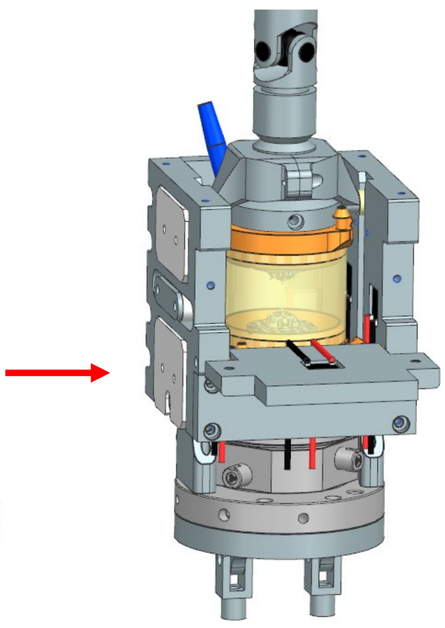

Fig. 2

Motion connector and pushrod for load application (grey); heating elements for incubation (black/red); incubation chamber within (orange).

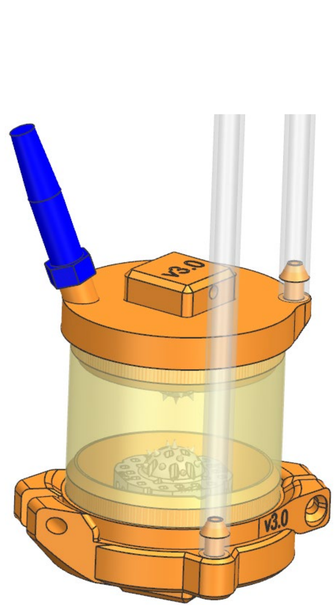

Fig. 3

Incubation chamber with temperature probe (blue) and IVD interfaces (grey).

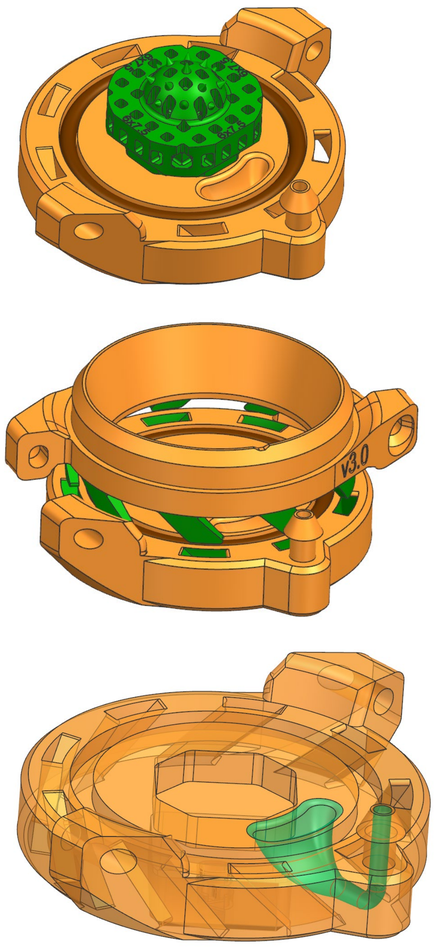

Fig. 4
Detail view of the chamber functions.

Top – Intervertebral disc interface.
Middle – Locking mechanism for sealing.
Bottom – Fluid channel to bypass the seal.

Fig. 7

Flexible incubation chamber for multiaxial load application.

Fig. 6

Fluid exchange in progress.

Fig. 5

Removable interfaces with different topologies for load transmission into the IVD endplates.

**Task**

The Institute of Medical Technology conducts intervertebral disc (IVD) research together with the European Space Agency. The aim is to investigate why astronauts often suffer from pain in the lumbar spine after a stay in space and gain new insights into why and how degenerative processes in intervertebral discs occur.

The IVD bioreactor was developed as part of the research, which enables realistic multiaxial load simulation. The bioreactor is thereby mounted on a microgravity simulator called a Random Positioning Machine (RPM), as seen in Figure 1. This allows load conditions with or without the influence of gravity to be investigated.

In this work, the incubation system, a central element of the bioreactor, was to be further developed to obtain a robust, reliable, and reusable incubation chamber that can transfer multiaxial loads into the intervertebral disc. In addition, the mechatronic system is to be optimized for the execution of long-term experiments.

**Method**

The chamber to be developed must meet various requirements, ranging from the flexible design (to transmit the induced multi-axial loading) to the fulfillment of strict biocompatibility requirements. This results in several sub-functions being developed in parallel using an iterative, pyramid-shaped approach:
The individual sub-functions are gradually combined and subjected to reliability tests until all are merged into a single system meeting the requirements.

**Results**

A chamber was successfully developed that allows the incubation of the IVDs with simultaneous load application. The chamber is divided into a rigid base and lid element, and a flexible cylindrical side wall connecting the elements (Figure 3). The load application is achieved with the IVD interfaces mounted to the chamber base and lid, fixing the IVD in between. These interfaces have a special surface topology that is pressed into the cartilaginous end plates of the IVD and can thus transmit the required multi-axial forces to the tissue.

Incubation is achieved by heating parts of the mechanical system for load induction using resistance heating elements (see Figure 2). These elements are controlled with the feedback of a temperature probe fitted to the chamber, which decouples the heating system from the chamber and significantly simplifies handling.

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