LuCa Phantom Vent V2.0

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An anthropomorphic breathing phantom was initially built for the Paul Scherrer Institute (PSI) to explore and simulate tumour motion in the lungs for scientific exploration of proton radio therapy of moving organs. For the Radiotherapy Center at the Clinic Hirslanden, CSEM has built a newer LuCa phantom version with a redesigned ventilation system to perform explorative measurements on their CyberKnife, Hislanden's non-invasive, robot-controlled radio surgical system for the treatment of tumours in any part of the body.

With the prototype ventilation system V1.0, PSI was able to perform many explorative radiation tests on moving lung tumours using the LuCa Phantom. The vent V1.0 system has an overall size of 400x480x600mm and weighs 39kg. It is driven by a heavy duty ring blower and four servo valves. The entire ventilation system is controlled by an external PC connected by USB using LabView-based software.

During the last two years users have reported new requests for the system such as: new interfaces for other measurement equipment, a respiration wave-form generator, DICOM file-import functionalities, self-calibration of the ventilation system, a miniaturized and lighter, portable ventilator system.

To make this ventilator system ready for small serial production, the Usability IEC 62366 & Risk management ISO 14971 approach were applied to redesign the entire hard- and software of the ventilator system.

System description Vent 2.0

The control unit has been integrated into the new ventilation system, enabling standalone capabilities and thus independent of the computer and its performance. In this scenario the PC is only needed for the graphical interface.

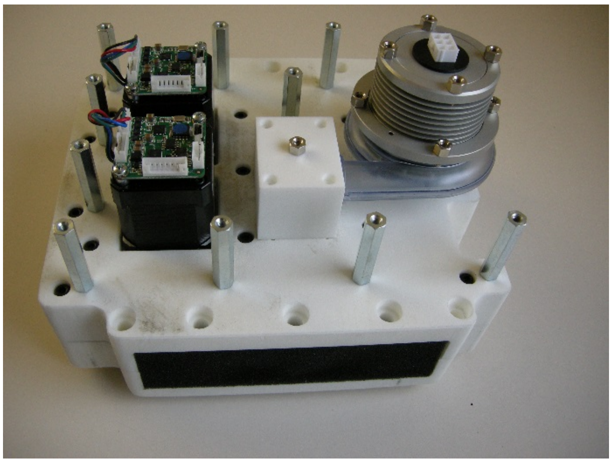

Figure 1: 3D printed air flow block with attached turbine and the two stepper-motors controlling the three-way valves.

All internal air ways and the mechanics of the valves are designed to be 3D manufactured by an additive manufacturing process (Figure 1).

To achieve the specifications, a powerful turbine, running at 35'000 rpm is integrated in a standard housing of 200x200x230mm, with a total weight of 8.1 kg. The maximum pressure levels that can be achieved with this system are +/- 30 mbars.

Figure 2 shows the programmed versus actual pressure in the lungs as displayed on the user interface. Motion of the tumour is directly correlated with the pressure and hence the volume of the lungs.

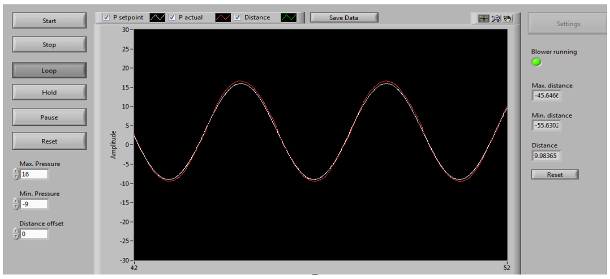

Figure 2: Main window of the GUI showing the pressure (applied and measured) and corresponding respiration curve.

The obtained results of the redesign fully match the requirements and its usability aspects. However at the current stage of miniaturization we experienced thermal issues running the ventilation system at full power for long periods.

Figure 3: Size comparison of the two ventilation systems.

In the third iterative development round we shall address the thermal problem of the turbine and try to reduce the noise caused by the air flow. Therefore a slight redesign of the hardware is envisioned.