THE LARGE DIAMETER CENTRIFUGE, LDC, FOR LIFE AND PHYSICAL SCIENCES AND TECHNOLOGY

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ABSTRACT

Recently a new centrifuge has been developed to serve the life and physical science community in conducting hypergravity experiments in a very versatile environment. The Large Diameter Centrifuge, LDC, has a maximum diameter of 8 meters. On its four arms a total of 6 free swinging gondola can be accommodated. Each gondola has a capacity of an 80 kg. payload that can be exposed to 20g. Each gondola is equipped with a series of utilities for the payloads. It provides a 220V power line, data communication for both monitor and commanding based on RS-232 serial connection, Ethernet or USB protocols. Each gondola has a video connection and sensors for temperature and acceleration. Different gasses can be supplied to each gondola. The gondola can house various instruments such as furnaces or modules for combustion sciences, fluid or plasma physics studies. The facility is also outfitted for long duration animal studies for basic research and in preparation for long duration space flight / microgravity experiments. Therefore each gondola is provided with potable water and air lines and is draft and light tight. In addition, a central, on-axes, gondola is foreseen to serve as rotation control for the hypergravity animals. The facility is fully programmable. Both, rotation profiles as well as experiment monitoring and commanding is performed via standard Windows-based LabView protocols.

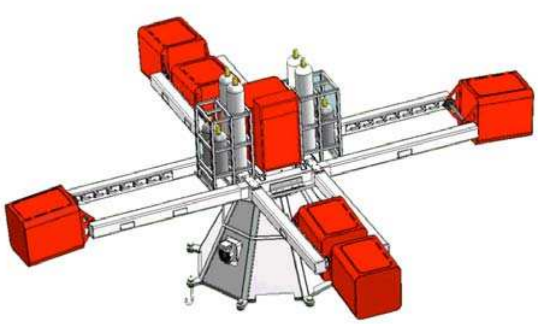

Fig. 1: Graphical view of the LDC when rotating at full speed (i.e. 67 rpm) with the 6 gondola swinging out. In the center of rotation is the 7th enclosure for rotation control in case of animal studies. Next to the 7th enclosure is room to store dedicated liquid or gas bottles.

1. INTRODUCTION

Countless research centrifuges have been built and used for *e.g.* plant [1], animal [2] or human studies [3]. Not only for life sciences studies but also in areas such as material and fluid sciences [4] or geology [5,6] centrifuges have proven to be very valuable to measure and understand how weight has an impact on life and physical systems. The LDC was drafted to be used for both life and physical sciences. In the life sciences domain we want to use the centrifuge for single cell, plant, lower organisms (like *Caenorhabditis elegans* or *Drosophila melanogaster*) but also for fish or rodents like mice and rats. To house a sufficient numbers of animals we require an adequate capacity, especially if we want to study weight effects in multi-generation studies (Fig.1). A gravity level of 10g is sufficient to cover most rodent studies [2]. Higher acceleration levels are more often used in single cell studies [7-9]. Same holds for physical sciences experiments [4]. Taken into account these consideration a maximum 20g was set for the LDC.

2. LDC MAIN FEATURES

2.1 Diameter

The Coriolis acceleration is a type of g-field that acts upon moving objects within a rotating system such as the Earth or a centrifuge. Coriolis accelerations, or cross-coupled responses, are due to the angular motion in two planes. It is an effect of rotation that contributes to the impurity of the gravity generated by a rotating system. For single cell gravitational research it is particularly involved in studies of relatively fast moving objects, like flagellates in hypergravity fields. In humans or animals, this acceleration is responsible for motion- and space- sickness while moving in a rotating field, mediated by action on the inner ears' semicircular canals. The impact of Coriolis is increased in a rapidly changing angular acceleration field such as centrifuges with relatively small diameters for generating a certain g-value compared to the velocity of the object studied but also the magnitude of the primary acceleration is important. Two rotating systems with different radii but spinning at similar rpm's would generate the same Coriolis accelerations. Coriolis was one of the main drivers for the 8 meter radius of the LDC [10]

2.2 Gondola

Special attention is given to the size and shape of the free moving gondolas. The internal volume of each

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gondola, 60×60×80 cm. is sufficient to house general purpose laboratory equipment such as regular microscopes or laser units. In order to reduce the drag of the gondolas several gondola shapes were evaluated. Rounded 80 mm. corners with a drag coefficient of 0.65 and drag value of 193 Newton at the maximum rim speed of 101 km/hr at 20g was chosen. The system has four arms. A total of six gondolas can be accommodated at once. The gondolas can be locked into one of the eight standard locations on each arm. The locking locations are 20 cm. apart. Internally each gondola provides several utilities such as power ($220V_{AC}$) and data (USB, RS232, video, Ethernet) to all individual gondolas. For long duration animal studies also potable water and gas lines are available in each of the 7 gondolas. Regular ambient air can be provided to the gondola or one can make use of the near the center placed gas bottles for dedicated pure gases or mixtures required for *e.g.* combustion studies. A seventh gondola is hard mounted in the center of rotation. This location can be used, in animal studies, as rotation control. With such a control it is possible to separate the hyper-weight effects from possible rotational effects.

2.3 Main Structure

The system is driven by 22 kW Siemens motor. Great attention was given to limit any vibrations within the system. Although vibrations are inherent to rotating devices the maximum vibration within a gondola at 20g was 0.0712 V_{rms}. The LDC main structure vibration spectrum while running at 20g (67 rpm, 1.12Hz) with six fully loaded (80 kg. each) gondolas was 0.12 V_{rms}. Both values are well within limits set for industrial machinery; ISO-10816-3/Class II that states an upper limit of 1.2 V_{rms}. In case of the off nominal condition with a maximum speed LDC (20g, F_{max}=39,2 kN) of only a single gondola with an 80 kg. payload mass, a maximum von Mises stress of 43 MPa results in a maximum deflection of the main hub structure of only 0.31 mm with a vibration (V_{RMS}) of 1.64 mm/s.

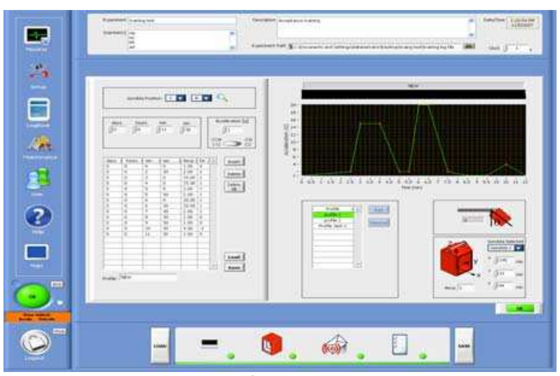

Fig. 2: Standard view of the system's operator display.

Power and data are provided to the rotating parts of the LDC by regular slip rings. Systems' as well as experimental data are collected on the rotating part by the programmable automation control PAC system. Data is converted to a standard Ethernet protocol and routed via a switch to the static part of the system where a second switch distributed the data over the control cabinet the operations and science work stations. In addition, eight hard wired video signals are routed from the rotating part into the control room. Safety lock sensors are located on each gondola door and gondola fixation point. Also motor temperature and speed are monitored. In addition, each gondola has a temperature and static accelerometer sensor.

2.4 Operations

The Windows-LabView based user interface for the LDC can be programmed to produce any gravity profile ranging from 1 to 20g (Fig.2). The science station is freely programmed by the user using LabView as main interface although dedicated packages may be used. The minimum speed-up time from 1 to 20g is 60 sec. The maximum speed-up or slowdown time is unlimited. Within an emergency stop procedure the LDC stops from 20 to 1g within 30 sec. The system cannot be started when gondola's are misplaced or when doors of the gondola or main rooms is not locked. Of nominal operations are automatically reported to the operator(s) and scientists via email and / or mobile phone text messages.

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4. ACKNOWLEDGEMENTS

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