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Paper Session I-C - Drop Tower Bremen -Short Time Microgravity Experiments During Free Fall

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Drop Tower "Bremen" - Short Time Microgravity Experiments during Free Fall
(An Overview)

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1 Introduction

In September 1990, the Center of Applied Space Technology and Microgravity (ZARM) of the University of Bremen, West Germany, will start the operations for the Drop Tower "Bremen". Drop Towers enable short time experiments under microgravity condititons, and are thus lowcost research facilities complementing the existing and projected space laboratories for microgravity research. Developed by ZARM in close cooperation with the Bremen based companies MBB/ERNO Raumfahrttechnik, OHB-System and Krupp Atlas Elektronik, the tower will realize up to several times per day to produce micro-gravitational condititons for approximately 4.7 s in free fall over 110 m. A powerful pumping system by which the drop tube can be evacuated to a pressure of 1 Pa, reduces the air drag to a negligible level. By using a special release system, the rotation and vibration of the experiment capsule during drop can be minimized. In constructing the tower system, great efforts were made to detect and to eliminate further disturbance effects. Experimental studies were carried out on a 18 m high drop tower at ZARM during the last 2 years. These studies are complemented by theoretical investigations and calculations of drop capsule models and platforms used for mounting the experimental equipment inside the drop capsule. The results of these studies and considerations show that the rates of the residual disturbing accelerations, to be attained during free fall at the Drop Tower "Bremen" in the interesting frequency range from 0.2 Hz to 1 kHz can be reduced to a level of 10^{-6} g [1]. As a result of these extremely low residual disturbing accelerations, the Drop Tower "Bremen" is not only a lowcost, but also a very high quality microgravity laboratory.

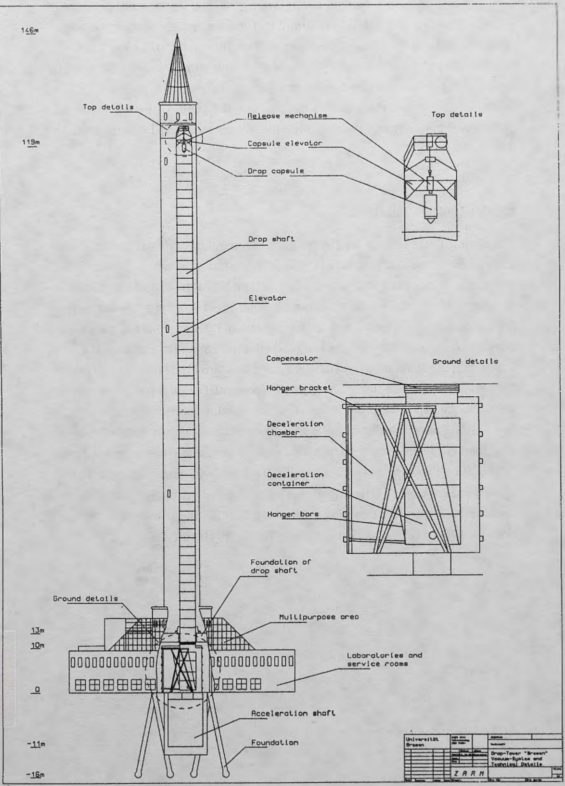
2 Tower and Drop Tube

The Drop Tower "Bremen" is a 145.5 m high building located at the area of the University of Bremen. The tower consists of a concrete shaft of 8.5 m diameter. Inside the shaft with a 25 cm thick concrete casing, the drop tube made of 8 mm to 15 mm thick welded steel is erected extruaxialy to the tower axis 1.75 m to the north. To minimize the transfer of force induced by wind, the drop tube is freely standing without any link to the surrounding concrete shaft on a 2 m thick concrete ceiling above the deceleration chamber at the tower foot. The deceleration chamber of 10 m height and 9 m diameter is integrated in the tower foot of 16 m height with a 30 cm thick concrete casing and an inner diameter of 14 m. Below the deceleration chamber, an additional 12 m deep concrete shaft is integrated in the tower foundation [2]. A later expansion phase includes the construction of a launching ramp in this shaft, which will enable the execution of a "vertical parabola" in the tower, thus doubling the duration of the microgravity experimental time. Fig. 1 shows a cross section of the tower [2].

3 Vacuum Chamber and Pumping System

The air resistance of the fall capsule would lead to a great disturbance of the microgravity quality, if the drop tube were not be evacuated. According to theory it can be easily obtained that the increase of the disturbing acceleration is a linear function of the air density and the square of drop time.

Fig.1: Drop Tower "Bremen" - cross section



To attain a maximum disturbing acceleration of 10^{-6} g, the minimal pressure of 1 Pa can be calculated [2]. Therefore, the drop tube and the deceleration chamber, forming the vacuum chamber with a volume of about 1700 m^3, can be evacuated with the help of a system of 18 pumps with a nominal pumping capacity of 32000 m^3/h down to the residual pressure of 1 Pa in about 1.5 hours. During 40 min the chamber must be flooded after every drop. Because of the short pumping and flooding time the tower can be used several times per day.

4 Drop Capsule and Design

The drop capsule used at the Drop Tower "Bremen" has cylindrical shape with 800 mm diameter and 1500 mm length. In front of the capsule, a cone of 500 mm length is mounted, with which the deceleration of the capsule is reduced to an acceptable level. The batteries for the experiment power supply during free fall are placed in the lower part of the capsule. In the upper part of the capsule the electronic platform with the installed onboard computer is plugged in. Therefore, the remaining payload area has a height of 1200 mm. The experiment hardware within the drop capsule is accomodated on a variable number of horizontal experiment platforms. They are fixed to four vertical stringers, one of which is removable in order to ease installation and removal of fully equipped platforms. Stringers, platforms and the capsule cone are made from AlMg-alloy. The experimental platforms are a sandwich construction made from wood covered by thin Al-plates. The sandwich construction was chosen because ot its excellent damping quality. Fig. 2 shows the schematic cross section of the drop casule used at the Drop Tower "Bremen".

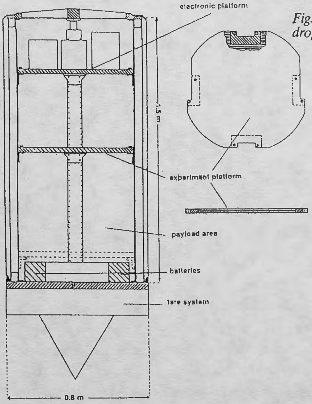


Fig.2: Cross section of the drop capsule

After integration an air-tight cover is sliped over the stringer structure to guarantee normal atmospheric conditions in the capsule during the experiment. By means of the tare unit, the capsule's center of mass can be moved exactly to the cylindrical capsule axis. The circular symmetric mass distribution is important to avoid an asymmtric transfer of momentum during the release process, and therefore to prevent a rotation of the capsule during free fall. The total mass of the capsule is about 300 kg including a payload of 180 kg in maximum [2].

5 Release Mechanism

Before free fall the capsule is hold by an electro-pneumatical tensioning element which is schematically shown in fig.3.

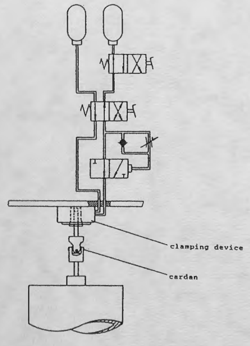


Fig. 3: Schematic drawing of the tensioning element

The tensioning element is similar to a drill chuck which hold the capsule by a 10 cm long bolt. If the fusioning force is reduced very rapidly by pressure increase, the bolt releases the capsule guided, so that a minimum of turning momentum is transfered to the capsule. As it can be seen from fig.4 , the vibrations induced during the release have been damped within 0.15 s. With this special release mechanism, the capsule rotation can be lowered to less than 0.2 °/s, which is related to a centrifugal acceleration of 10^{-6} g in 1 m distance to the center of mass.

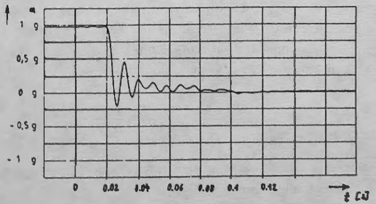


Fig.4: Acceleration in direction of the vertical capsule axis vs. time after release

6 Deceleration after Drop

The capsule of 300 kg mass has a final velocity of about 45 ms^{-1} after 4.74 s free fall and is decelerated over a distance of only 8 m. The capsule strikes a tank filled with 90 m^3 fine-graded polystyrol. During the impact, the capsule is decelerated to zero velocity within 0.2 s by a maximum deceleration rate of 30 g. Therefore, usual laboratory equipment without any shockproofed construction can be used. Fig.5 shows a typical deceleration curve.

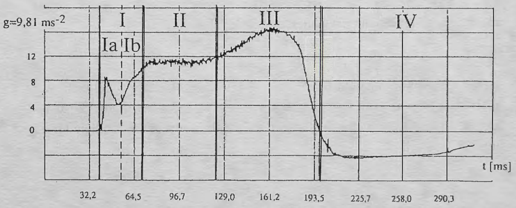


Fig.5: Deceleration rate, measured in vertical capsule axis, vs. time

7 System Controlling and Data Handling

All system and experiment data are collected and monitored in a control center. The tower system is controlled by a two-processor computer which allows the operator to control machines and instruments in their current status by simultaneous display and process-flow-diagrams. Therefore, the system can be run only one operator.

in addition, the experimenter can also monitor and control the experiment. The data are transmitted by a telemetry and command system, which provides in total 32 analog and 16 digital input channels for capsule system and experiment data. The maximum sampling rate is 11 kHz. The data are downlinked and stored in the control center and can be subject to on-line processing and "quick look" monitoring. During the experiment pre-phase (preparation, pump-down) the data are recorded with 10% of the maximum data-rate of 1 Mbit/s directly to a hard disk as a complete experiment-logging. Beginning with the release-permission-command (2 s before release) the data are recorded with maximum data rate to the TM-ground-station. After the end of the drop, the information is immediately saved on hard disk to be read out by the experimenter. Already during the pre-phase and the experiment itself, a part of the data-flow is directed to the experiment-control-computer for on-line processing and transmitting telecommands to the capsule [2].

To store housekeeping data and to acquire individual experiment data, an on-board data handling and storage system is available and offers in total 20 analog and 16 digital input channels as well as 2 analog outputs and 12 digital outputs [2].

For usual observation, a color video system is installed. One video channel is provided for monitoring the experiment on a high-resolution color-video-screen.

8 Electrical Power Supply

To support also experiments with high current requirements, e.g. melting and solidification experiments, the internal battery supply with a nominal voltage of 28 V has a total capacity of about 600 W. Peak currents up to 100 A for 8 ms are possible during free fall. Before release the capsule is supplied from an external power supply, which also charges the capsule batteries. During the release the connector to the external power supply is drawn by the capsule weight, and the internal power supply will be activated [2].

Acknowledgement

The Drop Tower "Bremen" project is a cooperative project between ZARM and the Bremen based companies MBB/ERNO-Raumfahrttechnik, OHB-System, and Krupp-Atlas-Elektronik. The financial guarantors are the State of Bremen, the German Federal Ministry for Research and Technology (Grant No.: 01 QV 87294), the German Federal Ministry for Education and Science, and the three companies named above. The authors acknowledge the financial support, and would like to express their sincere thank to all participants fore promotion and cooperation.

References

[1] H. Dittus, C. Eigenbrod, U. Kaczmarczik, J. Middelberg, H.J. Rath, B. Schwark: High Quality of Microgravity Environment during Short Time Experiments on the Drop Tower "Bremen" - Classification and Elimination of Disturbances Effects. Proc. 7th ESA European Conference "Fluid and Materials Sciences in Microgravity", Oxford 1989, in press.

[2] ZARM: Drop Tower "Bremen" - User Manual, ZARM, Universität Bremen, 1989.