UNIVERSITY OF ICELAND
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

EARTHQUAKE ENGINEERING RESEARCH CENTRE
UNIVERSITY OF ICELAND

University of Stavanger

Earthquake Simulator - Hexapod

Steinar Þór Bachmann[1], Ragnar Sigbjörnsson[1] and Jónas Þór Snæbjörnsson[2]

1) Earthquake Engineering Research Centre, University of Iceland, Austurvegur 2a, 800 Selfoss, Iceland.
2) Faculty of Science and Technology, Department of Mechanical and Structural Engineering and Material Science, University of Stavanger, Kjølv Egelands hus, N-4036 Stavanger, Norway

Objective

Many concepts in structural dynamics are best demonstrated through "hands-on" experiments. Physical simulators such as shake tables are an ideal tool for education and training within the field of earthquake engineering and structural dynamics (Dyke et al., 2000). They are also vital for calibration and testing of equipment as well for testing analytical models.
For this purpose a 6DOF motion simulator, Hexpod has acquired. To demonstrate the capabilities of the Hexapod as well as the basic principles of structural dynamics, a simple model has been designed and built. The structural response of the model has been observed and measured for various type of excitation.

Introduction

The Hexapod was acquired after careful consideration of the available equipment to suit the objectives. Quanser Inc. has a long tradition in providing research equipment to Universities. They had several small scale shake table concepts suitable for educational and research, that could fit the budget achievable for this purpose.
After a 2 year application process, the financing and purchase of the Hexapod introduced herein was realized in spring 2010. The Hexapod was financed by a grants from the University of Iceland Research Fund, RANNIS (The Icelandic Centre for Research) and EERC. The largest contributor being RANNIS.
The Hexapod arrived in Iceland in June 2010. Since then it has been tested at the Earthquake Engineering Research Centre in a variety of set-ups, including earth-quake simulations and structural studies of buildings subjected to ground excitations. This poster introduces the Hexapod, displays data from simulations and illustrates how the shake table can be used in teaching structural dynamics and earthquake engineering at the Civil Engineering Facility of the University of Iceland.

Figure 1
The Hexapod shake table supporting a two story structural frame model equipped with two accelerometers. In the background are control and monitoring devices.

The Hexapod

The Hexapod is a parallel robot device, capable of moving heavy loads, up to 250 kg at high acceleration. The motion platform is held up by 6 arms that are moved with 6 linear ball screw actuators that are drive by 6 DC motors. The ball-screw is based on a high-quality, low backlash linear guide with a total travel of 30 cm (i.e. ± 15 cm) and is driven by a high torque direct drive motor. All six arms of the platform meet at a flat rectangular base, the end-effector of the robot. A revoult joint fastens the arms to each motor. For maximum safety, a motor brake control employs the Hexapod's brakes when the joints reach their limit. This ensures the powerful motors do not damage the device or the load it carries (Quanser, 2010).
The Hexapod is controlled through a PC computer and the setup is relatively effortless. The control software used is Simulink and Matlab.

Hexapod – Control procedures

The Hexapod is controlled through a Simulink model in Matlab. Six different Simulink models and a setup files are provided by Quanser Inc. Every Simulink model has a different purpose, but the main model is the Hexapod-World-Control. Through that routine all the movements of the Hexapod are controlled. The movements are displacements along the 3 primary axis and rotations around every axis, a total of 6 degrees-of-freedom. When the desired movements for the Hexapod have been chosen the data goes through a variety of blocks, calculating the movements of individual arms in order to produce the overall motion desired.

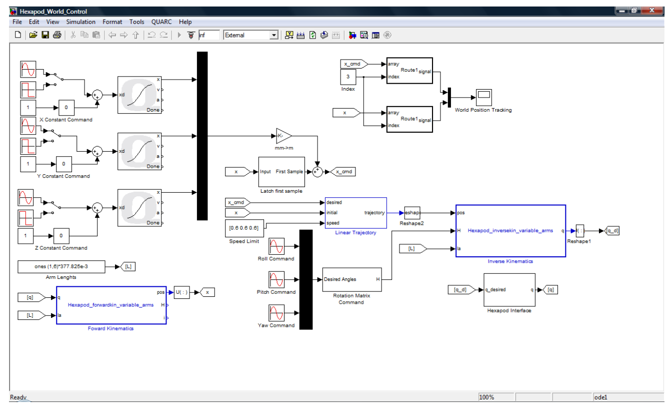

Figure 2
The Hexapod-World-Control model. Before working with this model the Hexapod has to be setup, calibrated and put in 'home' position with other setup files and Simulink models.

The movements of the Hexapod is controlled through commands determining the position or displacement of the platform, along or around the axis. This makes recreation of earthquakes a bit complicated process, because the acceleration data needs to be converted to a representative displacement and rotation data. The recreation requires time consuming calculations such as double integration and filtering of the data.

The Hexapod – The data aquisiton process.

When acquiring data several devices are used in monitoring the motion. The sensors used so far, are strain-gage based accelerometers that require a connection to a strain-gage bridge and amplification. The data from the bridge/amplifier module then goes through an Analog-Digital converter to the computer where the data is stored. The analog acceleration data from the strain-gage bridge is also monitored on an oscilloscope.

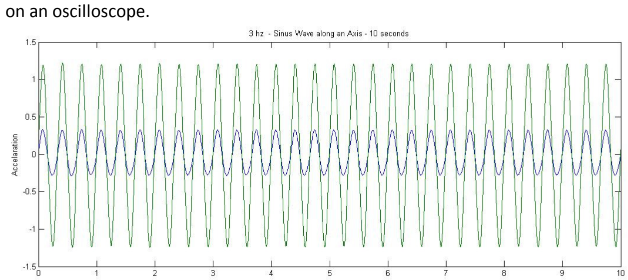

Figure 3
Data from a sinusoidal wave showing the acceleration in the middle and on top of the two story structural frame in figure one.

Conclusions

The Hexapod can be used in variety of applications associated with dynamic motion simulation. It is a useful device in structural dynamics and earthquake engineering allowing "hands-on" experiments. With a physical simulation tool of this type, researchers and students get the chance to recreate earthquakes and try out new theories that may lead to improved design of structures and help prevent damage due to strong earthquakes.

References

Dyke, S.J., Nepote, B., Caicedo, J.M., Johnson, S.J. and Oware, E., "Earthquake Engineering Education: A Modern Approach," *Proc. of the ASEE,* 2000.
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