ON-LINE CONTROL OF THE SINGLE COMPONENT SHAKING TABLE

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SUMMARY

Investigations were carried out at the Institute of Earthquake Engineering and Engineering Seismology, Skopje aimed to study the ways and the factors influencing provision of good reproduction of earthquake motion on the seismic shaking table.

Emphasis was placed on the selection of the most suitable variable for control, determination of the most adequate way of excitation generation, accurate definition of the dynamic behaviour of the system and determination of the constant and variable parameters which are considerably influencing the quality control of the vibration of the shaking table.

Software has been developed for on-line control of the shaking table, e.g. simultaneous exciting signal generation and data acquisition.

In this paper included are the most interesting results and conclusions.

INTRODUCTION

A single component shaking table has been operated for five years at the Institute of Earthquake Engineering and Engineering Seismology, University of Skopje, Yugoslavia. The system has been designed for testing of small scale models subjected to an earthquake time history or other types of motion. Data control and acquisition is carried out using a PDP 11/45 computer. The basic software for control and data acquisition is developed by the Institute staff, and it has been continuously modified in the past period. The on-line control and data aquisition concept presented in this paper has been developed recently, and it has some advantages above other concepts based on the off-line control. The same concept will be accepted for developing software for a large two componental shaking table system which is under construction at this Institute. The future improvements and modifications of this software will be made in order to make reproduction of the required earthquake time history as adequate as possible. The criterion for the earthquake motion reproduction quality adequacy is estimated based on the frequency response spectra reproduction quality.

During the past few year research, special attention was paid to finding the way for reproduction of the required acceleration time history, both to their forms and their peak values. The existing system uses displacement control and thus reproduction is quite good. Displacement time histories for certain earthquake are taken either from publications or they are derived by double integration procedure of the earthquake acceleration time history. The control of the displacement is linear, and it exists in the range from span 50 to span 1000. However, if we like to compare peak values of the acceleration time history by linear changing of the span, acceleration peak values show significant nonlinearity. In the future investigations efforts will be made to find the reasons of this nonlinearity, and to write software

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for required peak acceleration value control of the shaking table reproduction.

SHAKING TABLE AND ASSOCIATED SYSTEMS

The earthquake simulator consists of three major parts : shaking table, system for generation of controlled vibrations and electronic analog control system.

The shaking table has only one degree of freedom and it is horizontal translation.

The system for generation of controlled vibrations is consisted of hydraulic power supplies, hydraulic actuator and servovalve. The servovalve is driven by a valve controller.

The electronic control system is consisted of : program selector, program conditioner, servo controller, valve controller, DC transducer conditioner, AC transducer conditioner and feedback selector. The high quality displacement transducer (LVDT) and load transducer (load cell) is intended for control and readout. The functional block diagram of the earthquake simulator is presented on the Figure 1.

The electronic control system and hydraulic system are designed for control of displacement or dynamic force. Because the earthquake simulator is primarly intended for simulation of earthquake motions, it is most reasonable to have always displacement control of the simulated motion.

For improvement of the control capabilities of the electronic control system some changes on the program conditioner, valve controller and AC transducer conditioner were made. With these imporvements the noise level is lowered to less tnan 1% of full scale.

Standard computer system with a special peripherals (subsystems for analog to digital conversion and digital to analog conversion) is used for data processing, generation of exciting signal and data acquisition. The functional flow chart of data processing, control and data acquisition is presented in Fig. 2.

The electronic control system provides effective means of programming. In general, two means of implementation are used; analog and digital programming. As programming devices function generator, pseudo random generator, FM tape recorder and digital to analog converter as special computer perpheral can be used.

The exciting signal from programming device can be acceleration, velocity and displacement signal. If the exciting signal is not displacement signal, the program conditioner integrates the exciting signal twice (acceleration) or once (velocity), and the actual command signal is always displacement signal.

There are many reasons for using digital computers for programming and control of the system.

- The computer can pre-process acceleration time history into convenient displacement signal. The numerical integration is sufficiently accurate for low frequencies. With base line correction and digital band pass filtering it is possible to prepare very qualitative displacement command signal with known frequency spectrum and known peak values in the time domain.

- The computer program can provide ideal synchronisation of control and acquisition start up.

- It is possible to make accurate programming of displacement amplitude.

The programming and operating procedure is very easy.

ON-LINE CONTROL AND DATA ACQUISITION SOFTWARE

Simultaneously generating exiting signal for the shaking table and acquiring data from the test specimen and the table motion, the computer has complete control over the performance of the test. The same computer program (flow chart is given in Fig. 3) moves digital values of the chosen time history into D/A converter and activates A/D converter, thus providing ideal synchronisation.

Digitized time histories are usually available at sampling rate of either 50 Hz or 100 Hz. Linear interpolation has been done with sampling rate of 1 kHz which is optimum considering CPU speed and D/A converter noise level and more than enough considering seismic signals frequency range.

Data acquisition can be performed at sampling rate of either 50 Hz or 100 Hz.

Time scaling is implemented, so the basic time interval can be "compressed" from its real value up to 0.5 of it, in steps of 0.1. Time scaling applies to exciting signal as well as to data acquisition which provides proper sampling rate of acquired information.

Before the first digital time history value is applied to the shaking table, for 7 sec zero exciting signal is generated, then for 3 sec zero-offset information is acquired and in 10 sec the shaking table is slowly moved to its initial position. After the last time history value is reproduced by the shaking table, data acquisition process goes on up to 5 sec.

Computer programs for preparing time history data for generation process as well as row acquired data initial processing are executed regardless the test performance.

AN EXAMPLE OF SIMULATED TIME HISTORY

Many tests have been performed for research purposes of the dynamic performancies of the earthquake simulator and for development and improvement of programming and control procedures.

El Centro Imperial Valley record (N-S horizontal component), Parkfield (N65W, June 1966 earthquake), Montenegro earthquake (Bar, April 15, 1979 N-S), and several artificial earthquake time histories are used for the tests.

Command displacement (Fig. 5) presents double integrated original acceleration time history (Fig. 4). In Fig. 8 command displacement and recorded displacement are presented. The earthquake simulator follows the command displacement (Fig. 5, Fig. 7, Fig. 8), but there are differences between simulated (recorded) acceleration time history (Fig. 6) and the original acceleration time history (Fig.5).

Two major causes have strong influence on the accuracy of the simulated acceleration. The numeric procedure for calculating of the command displacement signal from given acceleration time history is not faultless, and bearing and sliding system of the shaking table and hydraulic part of the simulator cause uncontrolled acceleration spikes under displacement control.

CONCLUSIONS

Displecement exciting signal was chosen because the computer can pre-process the acceleration time histories into convènient displacement signal utilizing all neccessary numerical corrections.

On-line computer control of the test provides accurate synchronization, easy way of test parameters selection and simple operating procedure.

ACKNOWLEDGEMENT

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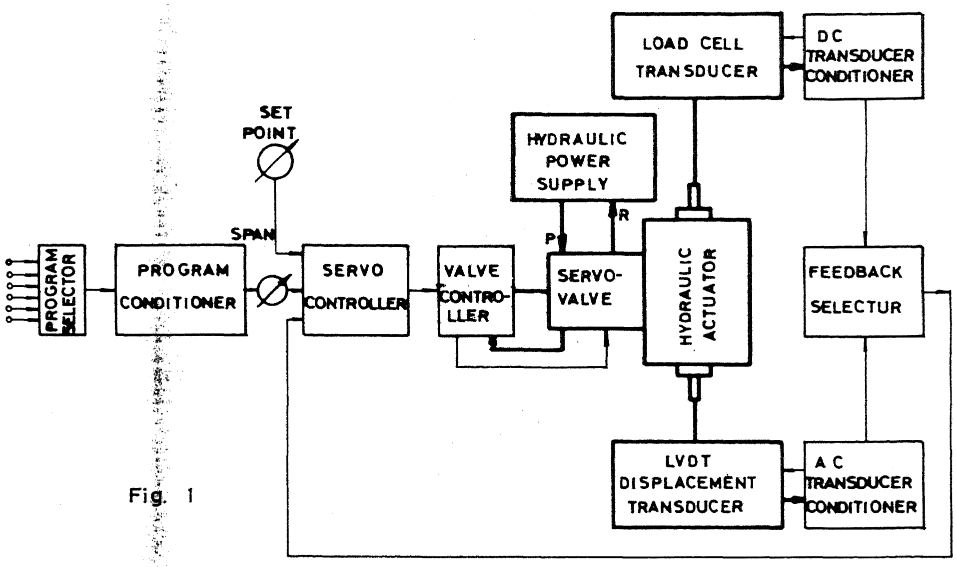

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Fig. 1

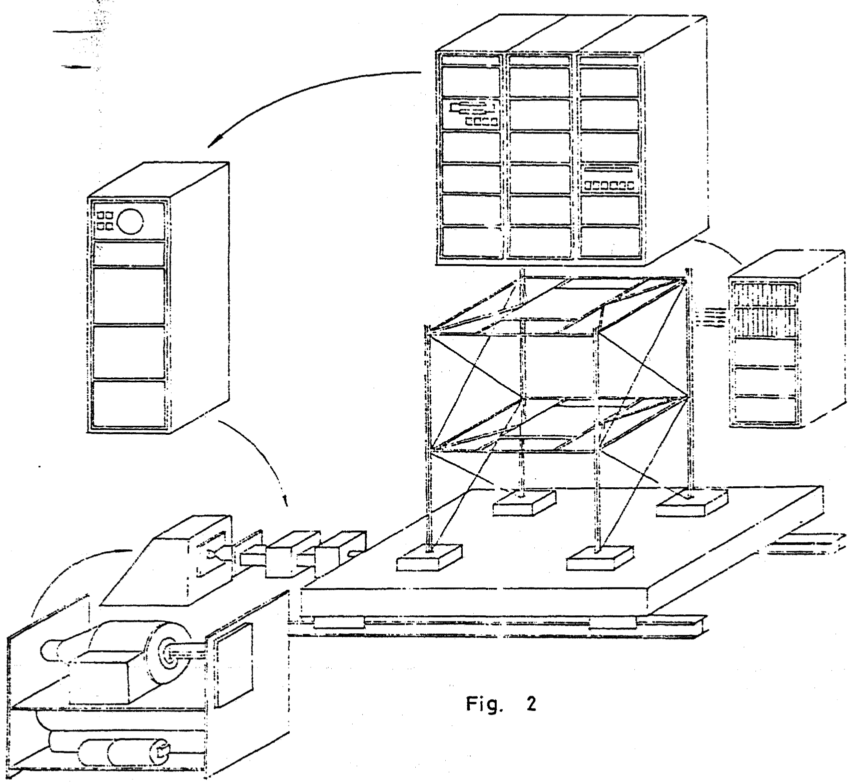

Fig. 2

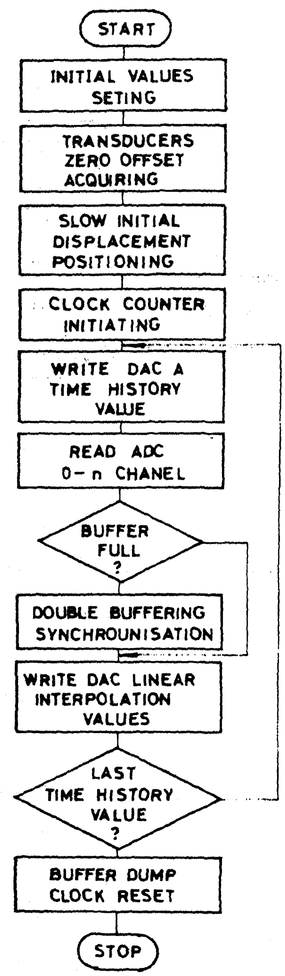
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Fig. 3

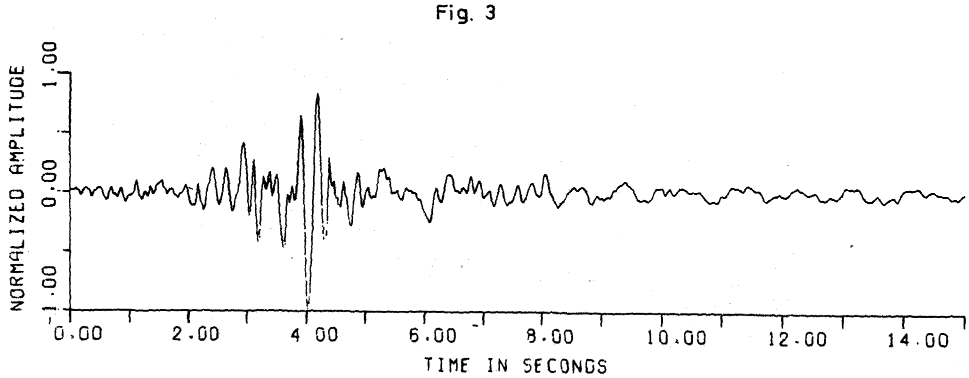
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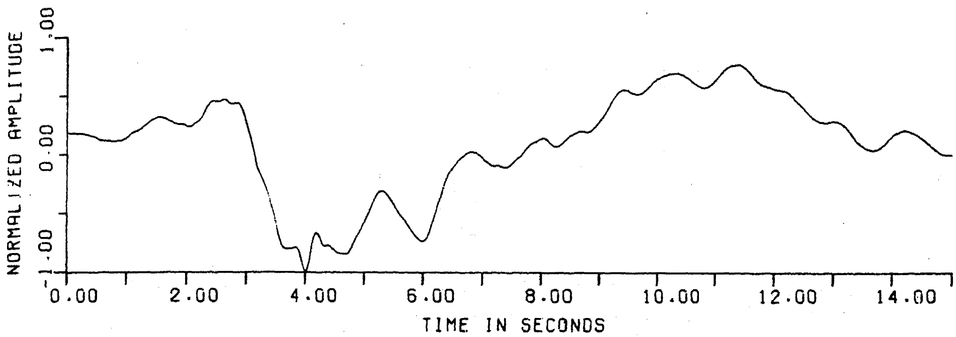
Fig. 4



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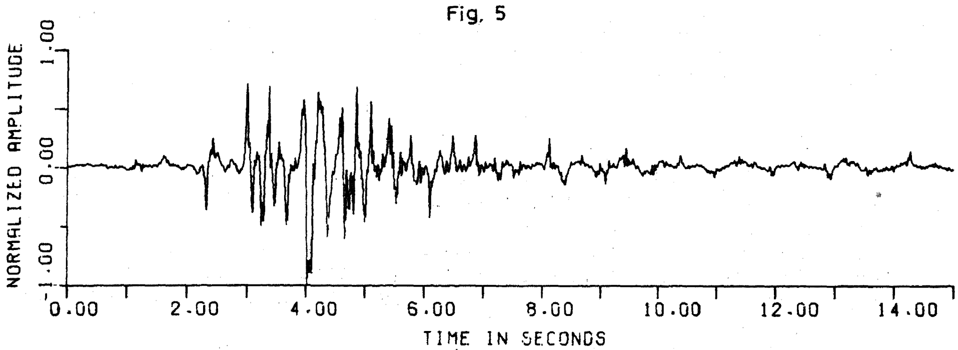

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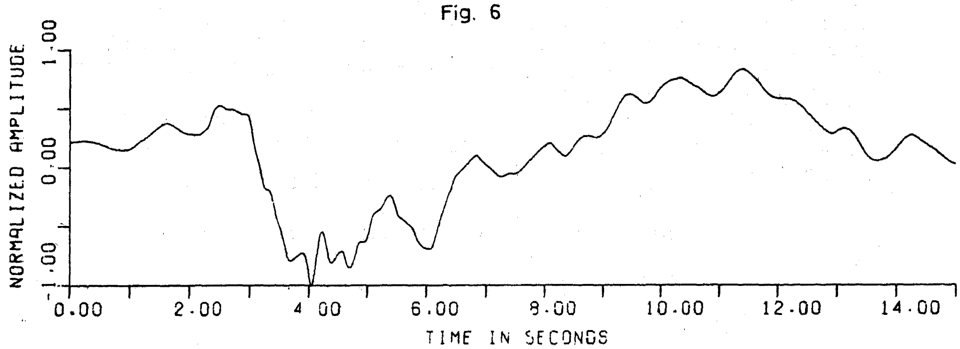

Fig. 7

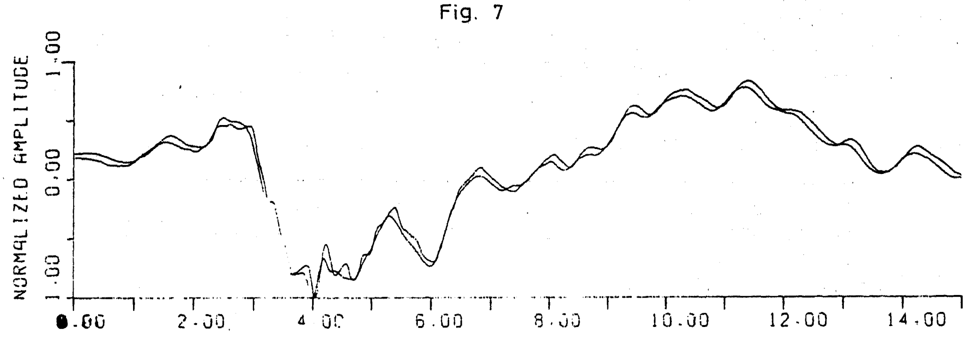

Fig. 8