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# Some Experimental Investigations for the Development of Integrated Model of a Structure with the Controllable Fluid Damper

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# SOME EXPERIMENTAL INVESTIGATIONS FOR THE DEVELOPMENT OF INTEGRATED MODEL OF A STRUCTURE WITH THE CONTROLLABLE FLUID DAMPER.

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## ABSTRACT

This paper presents a brief overview of research being conducted in the area of Seismic Hazards Mitigation. The focus of the study has been on the development of integrated model of a structure with controllable fluid damper. The damper is used with an objective of reducing the dynamic wave propagation potential in the structure, upon the structural excitation. Before its employability to serve the intended purpose, the system identification and the model validation are the pre-requisites for the optimal functioning of the damper. A phenomenological model of the controllable fluid damper-Magnetorheological damper is used along with other Smart materials in the experiments conducted under controlled conditions. The experimental results are used to verify the integrated system model. The experimental results obtained indicate that high performance can be attained with controllable fluid damper to meet the requirements associated with seismic response reduction in civil engineering structures.

## INTRODUCTION

Structural control systems fall into four basic categories;- passive, active, hybrid and Semi-active. Passive control systems have the limitations of not being able to adapt to structural changes and to varying usage and loading conditions. Active control systems operate by using external energy supplied by actuators to impart forces on the structures. The appropriate control action is determined based on measurements of the structural responses. A hybrid control system employs a combination of two or more passive or active devices. Because multiple control devices are operating, hybrid control systems can alleviate some of the restrictions and limitations that exist when each system is acting alone. Semi-active control device is one that cannot increase the mechanical energy into the controlled system, but has the properties, which can be dynamically varied to optimally reduce the responses of a structural system. Therefore, in contrast to the other structural control systems, semi-active control devices do not have the potential to destabilize the structural system, in the bounded input/bounded output sense.

### Semi-active structural control systems

These systems perform significantly better than passive devices and have the potential to achieve, or even surpass, the performance of fully active systems, thus allowing for the possibility of effective response reduction during a wide array of dynamic loading conditions. Of the conventional semi-active devices like variable fluid orifice dampers, controllable friction devices, variable stiffness devices, controllable fluid dampers are more reliable.

### Controllable-Fluid dampers

The essential characteristics of controllable fluids is their ability to reversibly change from a free-flowing, linear viscous fluid to a semi-solid with a controllable yield strength in milliseconds when exposed to an electric (ER Damper) or magnetic (MR Damper) field. This rheological metamorphism of these type fluids, acknowledging the receipt of dynamic waves to it, exploits its adoptability to mitigate the effects of natural hazards on the structures. MR Damper is used in these investigations**.**

This is an approach, wherein; the measured input/output data from the system is directly employed to consider a mathematical model that replicates the observed behavior. This is normally done either by Time domain approach or by the Frequency domain approach. Time domain approach is preferred where limited measurement time is available and the system is with more nonlinearity. Frequency domain approach is employed when the system is linear, time invariant and significant noise is present in the measurement. In this study, for the development of integrated model of a structure with the controllable fluid damper, Frequency domain approach of system identification is adopted, as the structure itself is assumed to remain in the linear region. System identification block diagram of the primary structure is as shown in Fig.1

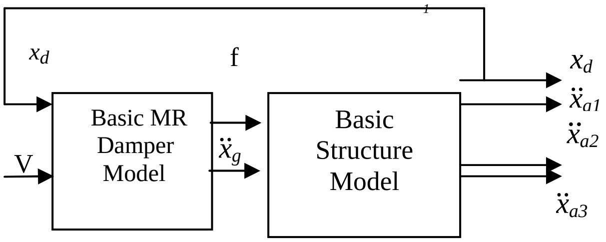

Fig. Block Diagram of the integrated structural system

Frequency domain approach

The methodology adopted in the present investigations, under this approach envisage

i) Experimental determination of Transfer functions
ii) Mathematical modeling of the transfer function and
iii) State space realization.

Inputs/outputs of the system

The two inputs are the ground excitation $\dot{x}_g$ and the applied control force f. The four measured system outputs include the displacement $x_d$ of the structure at the attachment point of the MR Damper, and the absolute accelerations, $x_{a1,} x_{a2,} x_{a3}$, of the three floors of the test structure i,e, y=($(x_{a1,} x_{a2,} x_{a3})$). Thus, a 4x2 transfer function matrix is identified to describe the characteristics of the system

EXPERIMENTAL PROGRAMMES

The experimental setup include a three storeyed steel structure (designed with its specifications as shown in Table-1) is employed with two Magnetorheological dampers- one installed between the ground floor and first floor and another between the first floor and second floor. Uni-axial accelerometers (Bruel & Kjare make) are used at each floor to measure the absolute accelerations. Force transducers are used in series with the dampers to measure the damping force and LVDT's are used to measure the displacements of the different floors of the model and to measure the displacement of the damper. The experimental setup is as shown in the figure.3.

The transfer functions from the ground acceleration to each of the measured responses were determined by exciting the structure with band-limited ground acceleration (0-50Hz). A series of tests were conducted to measure the response of the system with the dampers in place. The base of structure was excited and a command voltage is applied to damper (0 V to 50V). The force generated in the damper, absolute accelerations of the floors of structure, damper displacement and relative displacement of the structure at the three floors are measured. The behavior of developed integrated model response is examined, by conducting tests with broadband excitation (0-20Hz) with rms ground accelerations of 0.20g.

Discussions on results

The behavior of the damper is characterized by the following equations

$$C_1\dot{y} = \alpha z + k_u(x_d - y) + C_0(\dot{x}_d - \dot{y}) \qquad (1)$$

$$\dot{y} = 1/c_0 + c_1 + c_2)(\alpha z + c_0\dot{x}_d + k_0(x_d - y) \qquad (2)$$

*and the total force,*

$$f = c_1 y_1 + k_1(x_d - x_0) \qquad (3)$$

Figures **a-f** show representative magnitude for the experimentally determined transfer functions obtained using 12 averages. The three distinct, damped peaks 21.5, 84.168 Hz correspond to the first three modes of the structural system. The errors near the peaks in the transfer functions from the control force to the structural responses are due to the effect of control structure interaction. Six poles were necessary to model the input/output behavior of each transfer function in the frequency range of interest, to have 12 poles of the controlled system. A least-square output-error method with a non-linear optimization was employed to obtain 8-model parameter to model the damper. Optimization was done using MATLAB and optimized parameters were determined to fit the generalized model of Damper to experimental data.

CONCLUSIONS

The integrated system model is obtained by connecting the basic models of the controllable fluid damper and structure.

## REFERENCES

Akbay,Z .and Aktan.H.M.(1990). “Intelligent Energy Dissipation System”.Proc.of the fourth U.S.National conference on Earthquake Engineering, Vol.3,No.4.pp 427-435.

Carlson, J.D. and Weiss,K.D.(1994).” A Growing Attraction of Magnetic Fluids”,Machine Design,August,pp.61-64.

Cherry,S.(1994).”Research on Friction Damping at University of British Columbia.”Proceedings of International Workshop on Structural Control ,USC Publication Number CE-9311,PP.84-91.

Dyke,S.J.,B.F.Spencer,Jr.,M.K.Sain and Carlson, J.D.(1996a).”A New Semi-Active Control Device for Seismic Response Reduction,” Proc.11th ASEC Engrg.Mech .Spec. Conf., Ft Lauderdale, Florida.

Dyke,S.J.,B.F.Spencer,Jr.,M.K.Sain and Carlson, J.D.(1996b*)”* Seismic Response Reduction using Magneto Rheological Dampers,” Proc.of the IFAC World Congress ,San Francisco , California.

Ehrgott, R.C.and Masri,S.F.(1994).”Structural control Applications of an Electro Rheological Device“ Proceedings of International Workshop on Structural Control ,USC Publication Number CE-9311,PP.115-129.

Fedorov,V.A.(1992).”Features of Experimental Research into Characteristics of Magneto Rheological and Electro Rheological Shock Absorbers on Special Test Stands.” Manetohydrodynamics,Vol.28,No.1, p.96.

Gamota.D.R. and Filisko,F.E.(1991).”Dynamics Mechanical Studies of Electro Rheological Materials Moderate Frequencies.” Journal of Rheology,Vol.35,PP.399-425.

Gavin,H.P.(1994).” Electro Rheological Dampers for Structural Vibration Suppression.”Ph.D *dIssertation,* The University of Michigan, Department of civil and Environmental Engineering.

Kamnath,G.M.,and Werely,N.M.(1996).”A Non Linear Viscoelastic-Plastic Model for Electro Rheological Fluids .” Smart Materials and Structures,(Submitted).

Graselli,Y.,Bossis,G.and Lemarie,E.(1993*).”* Field Induced structure in Magneto Rheological Suspensions.” Progress in colloids & Polymer science.

Housner,G.W.and Masri,S.F.(Eds.).(1993) Proceedings of International Workshop on Structural Control ,USC Publication Number CE-9311,Univ. of Southern California.

Housner,G.W.and Masri,S.F.and Chassiakos,A.G. .(Eds.).(1994). Proceedings of First World Conference on Structural Control, Pasadena, CA, August3-5.

Inaudi,J.A.and Kelly, J.M.(1994*)”* Experiments on Tuned Mass Dampers Using Viscoelastic, Frictional and Shape-Memory Alloy Materials.” Proceedings of First World Conference on Structural Control, Pasadena, CA, August3-5.Vol.2,PP .TP3-107.

Kashevskill,B.E.(1990).” in Relaxtation of Viscous Stresses Magneto Rheological Suspensions .” Manetohydrodynamics,Vol.28,No.2, p.140.

Kawashima,K.,Unjoh, S. and Shimizu ,k.(1992).” Experimental on Dynamic Characteristics of Variable Damper .”proc.of Japan National Symposium on Structural Response Control,Tokyo, Japan.

Kordonsky,W.I.(1993b).” Magneto Rheological Effect as a Base of New Device and Technologies.” Journal of Magnetism and Magnetic Materials, Vol.122,No.1/3,p.395.

Kordonsky,W.I.Shulman,Z.P.,Gorodkin,S.R. and Demchuk, .SA.,Prokhoro I.V.,Zaltsgendler ,E.A. and Khusid,B.M.(1990).”Physical Properties of magnetizable structure Reversible Media .” Journal of Magnetism and Magnetic Materials, Vol.85,pp.114-120.

Kurata,N., Kobori,T.,Takahashi,M.Niwa,N. and Kurino,H.(1994) “Shaking Table Experiments of Active Variable Damping System .” Proceedings of First World Conference on Structural Control, Pasadena, CA, August3-5.Vol.2,PP .TP3-107.

Makris,N.,Hill,D.,Burton,S.and Jordon,M.(1995*)”*. Electro Rheological Fluid Dampers for Seismic Protection of Structures.”Proc.SPIE Conf. on .” Smart strucT. and materials.(I.Chopra,Ed.),San Diego, California.184-194.

Makris,N.,Hill,D.,Burton,S.and Jordon,M.(1996).”Analysis and Design of an Electro Rheological Damper for Seismic Protection of Structures.” Journal of Engineering Mechanics, ASEC, (in press).
MATLAB(1994). The Math Works, Inc. Natick, Massachusetts.

Minagawa,K.,Watanabe,T. and Munakata,M.(1994).”A Novel Apparatus for Rheological Electro Measurements of Magneto Rheological Fluids.” Journal of Non Newtonian Fluid Mechanics, Vol.52,No.1,p.59.

Patten,W.N.,Kuo,C.C.,He, Q.,Liu,L., and Sack, R,L.(1994*).”*Suppression OF Vehicle Induced *Bridge Vibration via Hydraulic Semiactive Vibration Dampers*.” Proc of First World Conference on Structural Control, Pasadena, CA, August3-5.,PP .FA1-30 through FA 1-38.

Savost'yanov,A.(1992*)*.”Effects of Magnetomechanical Relaxation in a Magneto Rheological Suspension ”Magnetohydrodynamics. Vol.28,No.1,p.42.

Spencer Jr.,B.F.,Dyke,S.J.,Sain,M.K. and Carlson,J.D(1996a).”Idealized Model of Magneto Rheological Damper,” Proceedings of the 12th conference on Analysis Computation , ASEC,Chicago,Illinois.

Spencer Jr.,B.F.,Dyke,S.J.,Sain,M.K. and Carlson,J.D(1996a*)*.”Non Linear Identification of Semi Active Control Devices.” 11th ASEC Engrg. Mech.Spec.Conf.,Ft.Lauderdale,Florida.

Soong,T.T.(1990).Active Structural Control Theory and Practice, Longman Scientific and Technical ,Essex,England.

Suresh Babu.S.*Magneto rheological Dampers*. A newparadigm in Base isolation Techniques in Earthquake engineering Proc.of INCONTEST 2003. PP 637-643,2003.

Suresh Babu.S Rheological Dampers for seismic Hazards Mitigation- A quasi static Model Analysis of Dampers Proc.of Inter.National conference INDEX 2006.PP 351-362;2006.

Suresh Babu.S, T.Govindswamy, G.Shyamala Assesing and Reducing Earthquake Impacts Proc.of Inter.National conference INDEX 2006.pp 492-501,2006.

Winslow,W.M.(1947).”Method of Translating Electrical Impulse Into Mechanical Force.” US Patent No.2,417,850.

Winslow,W.M.(1949).”Induced Fibration of Suspension .”Journal of Applied Physics ,Vol.20, pp.1137-1140.

Table.1.Specifications Of The Model Structure

| | | | | | |
|---|---|---|---|---|---|
| No.of bays | 01 | No.of columns | 12 | Span along X direction | 60cm |
| No.of floors | 03 | Wt of each floor (Kg) | 80 | Span along Y direction | 45cm |

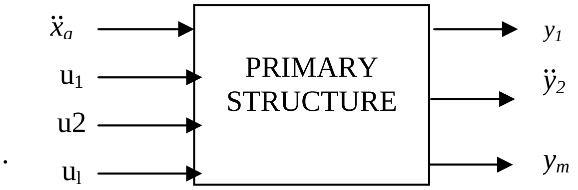

Fig.1 System identification block diagram of the primary structure

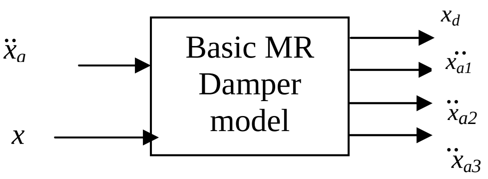

Fig. 2. Block Diagram of basic MR damper model

Fig. 3 Experimental Setup of a three storeyed steel structure

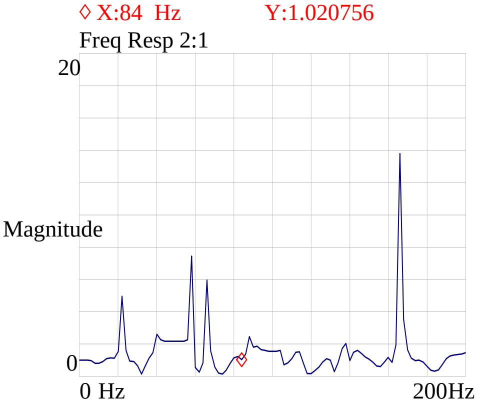

Fig. a. Control force to I floor acceleration

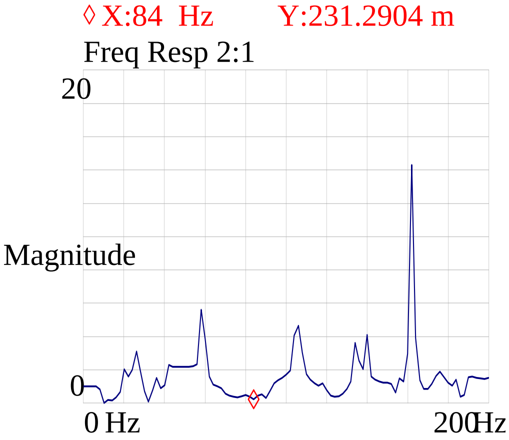

Fig. b Control force to II floor acceleration

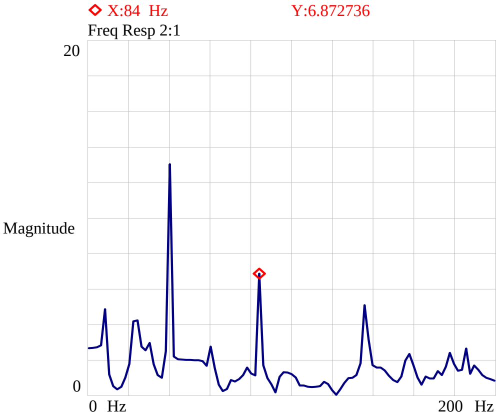

Fig. c Control force to III floor acceleration

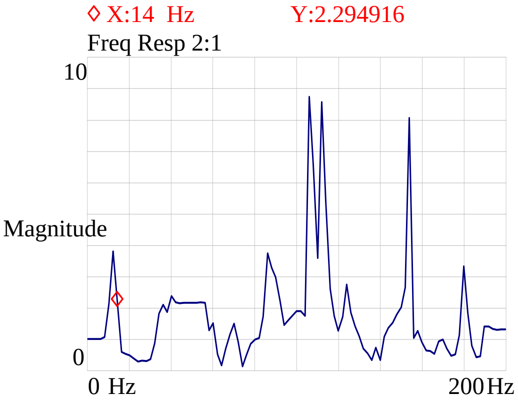

Fig. d Ground acceleration to III floor acceleration

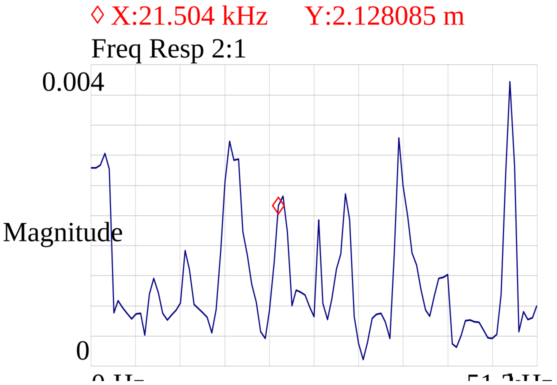

Fig.e Ground acceleration to II floor acceleration

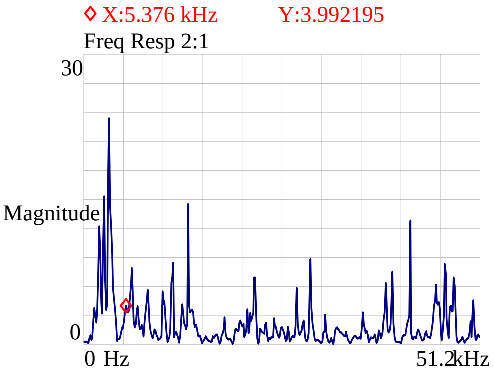

Fig. f Ground acceleration to I floor acceleration