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The Nested-Eccentric-Shells Damper with an Improved Approach to Increasing Hysteresis Behavior

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ABSTRACT: In this study, by the concept of control structures, a new shell configuration is designed for steel energy dissipative devices. This device is proposed for the protection of structures against earthquake forces. This device is named a nested-eccentric-shells damper (NESD). This damper is made of a large cylindrical shell that surrounded three small cylindrical shells. The conventional methods of welding or metal casting can be applied in constructing the NESD. The configuration of the shell-type components is designed in such a way that to be able as a combination of series and parallel springs. To assess the performance of this damper, numerical analysis, and full-scale testing are applied. Hysteretic loops obtained from the analysis with highly ductile performance are applied to determine the behavior of this proposed damper. The results indicate that the nested-eccentric-shells damper is of a stable behavior in hysteretic loops, and can provide appropriate damped energy subject to cyclic loading. However, to improve the performance and interaction of the internal members of this damper, a thickness ratio modification is proposed for the inner shells. The effectiveness and the usefulness of this modification in the numerical analysis have been proven in this study.

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1. INTRODUCTION

Passive control devices, including dampers, are useful devices for dissipating seismic energy in the structures. Yield dampers, the subject of this article, are common and suitable function in dissipating seismic energy [1]. The most popular yield dampers with plate mechanism are Added Damping and Stiffness (ADAS) [2], Triangular-plate ADAS dampers (TADAS) [3], and 'U-shaped damper' [4]. Recently, to enhance the function of metal components in yield dampers, some dampers with cylindrical shells such as 'pipe damper (PD) [5], 'Dual-pipe damper (DPD) [6], and centric pipe damper [7] are proposed. Accordingly, for improving the function of the dampers with cylindrical shells, a new configuration with eccentric cylindrical shells is proposed by the authors of this study [8]. These dampers are called Nested-Eccentric-Shells Damper (NESD). In this device, four nested eccentric cylindrical shell acts as a non-linear spring by a combination of series and parallel form and the members have a combination of both shear and axial behaviors. In this study for the increasing hysteresis behavior of this damper, an improved approach to modified thicknesses of the components is applied and the results verifying to non-modified models.

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2. METHODOLOGY

The configuration of the Nested-Eccentric-Shells Damper (NESD), as shown in Fig. 1, is constructed with four cylindrical shells (or pipes), with 406, 219, and 168 mm diameter and length of 150 mm. All diameters of the pipes correspond to that of the APL 5L (2000) standard. To evaluate the mechanical characteristics of NESD, some models are simulated by nonlinear finite element software (ABAQUS), and the numerical result are verified by the test of two full-scale prototypes in [8] study. In this study for enhancing the interaction of components and performance of the damper, by using the energy method in material strength (Castigliano's second law) for the ring [9], and apply it with the compatibility of deflection, a thicknesses ratio propose for the thickness of the inner damper members. According to this thicknesses ratio, the thickness of P.219 proposes 1.7 times to thickness of P.168. Accordingly, twelve numerical models with modified thicknesses of inner shells are modeled by finite element software to calculate mechanical properties.

3. RESULTS AND DISCUSSION

By using the proposed thickness ratio and modified thickness of inner shells in the M-NEDS, all numerical models are analyzed. Some of the important mechanical properties

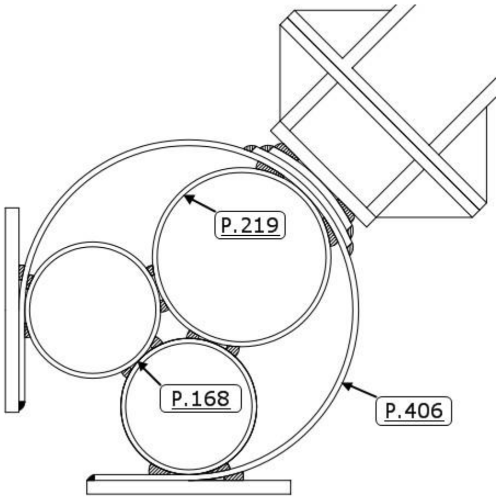

Fig. 1. Nested-eccentric-shells damper [8].

Table 1. Mechanical parameters for M-NESD.

Sample	Qy [kN]	m	Qu [kN]	n	δy [mm]	Dt [mm]	K_e [kN/mm]	c	t	K_{eff} [kN/mm]	Sr = K_{eff}/K_e
M-NESD.1	46.17	0.62	74.47	1.30	8.1	40.6	5.68	0.15	0.27	2.06	0.36
M-NESD.2	123.72	0.64	193.44	1.21	5.6	28.3	21.89	0.14	0.22	7.31	0.33
M-NESD.3	243.58	0.65	376.2	1.16	4.4	22	55.26	0.14	0.20	17.95	0.32
M-NESD.4	57.25	0.67	84.87	1.26	7.6	37.9	7.55	0.12	0.22	2.47	0.33
M-NESD.5	144.45	0.64	226.32	1.19	5.3	26.6	27.14	0.14	0.21	9.04	0.33
M-NESD.6	303.09	0.65	468.23	1.15	4.2	20.9	72.48	0.14	0.19	23.39	0.32
M-NESD.7	87.23	0.63	138.15	1.23	6.4	32.2	13.56	0.15	0.24	4.68	0.34
M-NESD.8	166.76	0.64	260.6	1.18	5	25.2	33.1	0.14	0.21	11.04	0.33
M-NESD.9	369.5	0.65	566.78	1.13	3.8	19	97.33	0.13	0.18	31.26	0.32
M-NESD.10	104.64	0.63	165.12	1.21	6	30	17.42	0.14	0.23	5.94	0.34
M-NESD.11	190.72	0.64	297.21	1.17	4.8	24	39.7	0.14	0.20	13.11	0.33
M-NESD.12	442.69	0.65	677.04	1.12	3.6	18	123.05	0.13	0.18	39.03	0.32

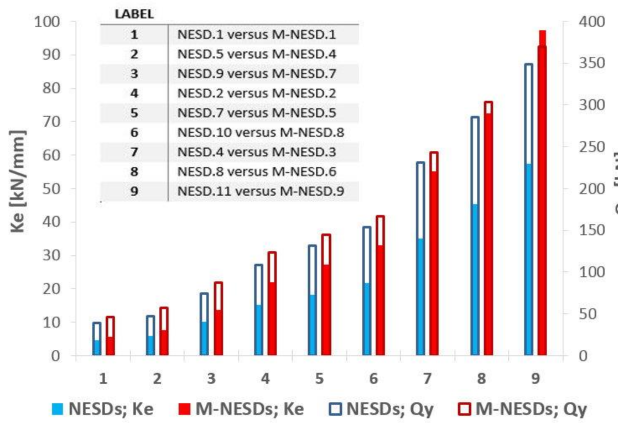

Fig. 2. The stiffness and stress for the NESD versus M-NESD models.

like yield force: 'Qy', ultimate force: 'Qu', the maximum plastic deformation: 'Dt', yield displacement: 'δy', the capacity of yield/ultimate force: 'm', elastic stiffness: 'Ke', effective stiffness: 'K_{eff}', tensile over strength: 'n', second stiffness factor at pressure: 'c' and second stiffness factor for tensile: 't', and Sr=K_{eff}/Ke, are tabulated in Table 1. To assess the improvement of hysteresis behavior of damper and increasing values of mechanical parameters in modified models, the elastic stiffness and yield force values of the nine modified models versus unmodified models are shown in Fig. 2. The average value of the equivalent

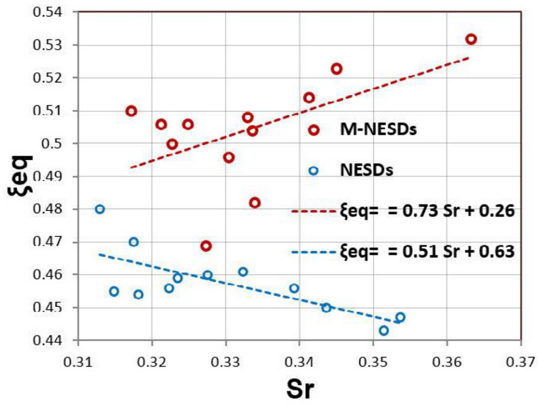

Fig. 3. Damping versus S_r ratio.

viscous damping according to hysteretic loops for M-NESD models is 47%. The effect of thickness ratio modification to enhance the equivalent viscous damping in the modified model, in Fig. 3 is shown.

4. CONCLUSIONS

In this study, to increase the performance of metal dampers, a new damper with a shell structure but with a complex mechanical mechanism has been proposed. To increase the performance of the damper the thickness of inner shells, modified by a proposed thickness ratio. After this modification, the function and mechanical properties of the modified model are increased, and the viscose damping of 4 % is upgraded.

REFERENCES

[1] Soong, T.T. and M.C. Costantinou, *Passive and active structural vibration control in civil engineering*. Vol. 345. 2014: Springer.

[2] Bergman, D.M. and S.C. Goel, *Evaluation of cyclic testing of steel-plate devices for added damping and stiffness*. 1987: Department of Civil Engineering, University of Michigan.

[3] Tsai, K.-C., et al., *Design of steel triangular plate energy absorbers for seismic-resistant construction*. Earthquake spectra, 1993. **9**(3): p. 505-528.

[4] Suzuki, K. and A. Watanabe. *Experimental Study of U-shaped Steel Damper [J]*. in *Summary of Technical Papers of Annual Meeting, Architectural Institute of Japan, B-2*. 2000.

[5] Maleki, S. and S. Bagheri, *Pipe damper, Part I: Experimental and analytical study*. Journal of Constructional Steel Research, 2010. **66**(8-9): p. 1088-1095.

[6] Maleki, S. and S. Mahjoubi, *Dual-pipe damper*. Journal of Constructional Steel Research, 2013. **85**: p. 81-91.

[7] Cheraghi, A. and S.M. Zahrai, *Innovative multi-level control with concentric pipes along brace to reduce seismic response of steel frames*. Journal of Constructional Steel Research, 2016. **127**: p. 120-135.

[8] Reisi, A., H.R. Mirdamadi, and M.A. Rahgozar, *Numerical and experimental study of the nested-eccentric-cylindrical shells damper*. Earthquakes and Structures, 2020. **18**(5): p. 637-648.

[9] Whidden, W.R. *Buried flexible steel pipe: Design and structural analysis*. 2009. American Society of Civil Engineers.

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