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APPLICABILITY OF EXISTING INDEXES OF NON-PROPORTIONALITY OF DAMPING IN CASE OF THEORETICAL MODEL OF SLENDER STRUCTURE WITH INSTALLED TMD

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Abstract: *The paper analyzes an applicability of to date published indexes of non-proportionality in the case of a linear viscously damped numerical model of slender structure equipped with tuned mass damper (TMD). The installation of TMD into the structure not only reduces the level of undesired vibration, but it can also cause due to damping element of TMD a significant increase of damping non-proportionality. The paper recommends the most suitable indexes for such a type of structure and points out to impropriety of the others. The point of view of is also focus on the validity of the existing criterions for neglecting of non-diagonal terms of a modal damping matrix. Only indexes and criterions based on the properties of the modal damping matrix were taking into account. The verifications of validity and recommendations for usage of particular indexes and criterions were performed using analysis of the dynamic response of an existing structure on harmonic excitation with and without neglecting of non-diagonal terms of modal damping matrix. The applicability was also checked using analysis of particular complex eigen-modes.*

Keywords: ***Indexes of non-proportionality of damping, tuned mass damper, slender structure***

1. Introduction

Numerically efficient solution of a dynamic response of linear viscously damped numerical models of real structures using modal superposition method motivates many authors to set boundaries, to which the inaccuracy of a solution with neglecting of non-diagonal terms of a modal damping matrix is still acceptable. Simultaneously, they attempted to quantify an extent of non-proportionality of the damping by means of indexes of various types. In this paper short summary of till now published indexes based on modal damping matrix and criterions for neglecting of its non-diagonal terms are presented. The applicability of these indexes and criterions is investigated in the case of slender structure equipped with one absorber which is subjected to the harmonic excitation. The applicability is assessed using comparison of indexes and criterions with character of complex eigen-modes and with relative errors of the response that are caused by neglecting of non-diagonal terms for selected values of damping ratios of absorber.

2. Results

Analysis of the response of a numerical model of real structure highlights the necessity of prerequisite of non-proportional damping, when passive damping equipment is installed into the structure and when the detailed behavior is investigated. The relative errors of the response of the top of the tower on harmonic excitation which was caused by approximate solution were significantly high even for real damping ratio of the absorber. Relative errors corresponding to peaks of response curve see Table 1 were subsequently compared with values of analyzed criterions and indexes for selected damping ratios of the absorber. None of investigated indexes and criterions did fully correspond to the obtained relative errors and character of complex eigen-modes. The summation based index suggested by

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Prater & Singh (1986), indexes proposed by Bhaskar (1995) and Venancio-Filho et al. (2001) indicated very high values of non-proportionality particularly for the first four eigen-modes for all selected damping ratios of absorber. Even for zero damping ratio for which the calculated errors of the response were negligible and also for the first eigen-mode, which is almost identical with real eigen-mode of the undamped system. Also the generalized index suggested by Tong et al. (1994), determinant based index proposed by Prater & Singh (1986) indicated almost total non-proportionality of the system for all investigated cases. The analysis confirmed that criterion suggested by Hasselman (1976) couldn't be used because it supposes the mechanical interaction between individual eigen-modes even for classically damped structures. The relatively good agreement between calculated relative errors and proposed criterions was obtained for criterion proposed by Warburton & Soni (1977). The boundary values of parameter ε for which the criterion is still fulfilled could also serve as an approximate index of non-proportionality of particular eigen-modes see Figure 1.

Tab. 1: Relative errors of peaks of response curve caused by approximate solution for selected ζ_{TMD} (In parentheses the corresponding eigen-frequencies of structure with absorber)

Peak n.	1 (f_1= 0,378 Hz)				Peak n.	2 (f_2= 0,679 Hz)			
ζ_{TMD} [/]	0	0,2	0,5	0,8	ζ_{TMD} [/]	0	0,2	0,5	0,8
ε_{Ytop} [%]	0,01	2,11	12,69	29,61	ε_{Ytop} [%]	0,03	37,15	79,40	89,61
Peak n.	3 (f_4= 1,275 Hz)				Peak n.	4 (f_5= 2,12 Hz)			
ζ_{TMD} [/]	0	0,2	0,5	0,8	ζ_{TMD} [/]	0	0,2	0,5	0,8
ε_{Ytop} [%]	0,02	9,16	45,74	68,60	ε_{Ytop} [%]	0,01	-1,97	0,38	9,33

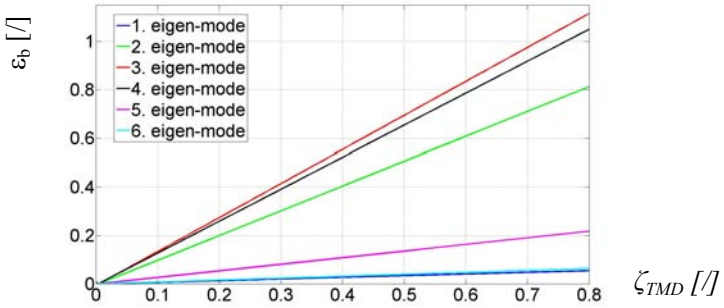

Fig. 1: Boundary values ε_b of criterion suggested by Wartburton & Soni (1977) as function of ζ_{TMD}

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References

Bhaskar, A. (1995) Estimates of errors in the frequency response of non-classically damped system. *Journal of Sound and Vibration*, 184 (1), pp. 59–72.

Hasselsman, T. K. (1976) Modal coupling in lightly damped structures. *AIAA Journal*, 14, pp. 1627–1628.

Hurty, Walter C, & Rubinstein, Moshe F, (1964) *Dynamics of Structures*, Englewood Cliffs: Prentice-Hall,Inc,

Prater, G. & Singh, R. (1986) Quantification of the extent of non-proportional viscous damping in discrete vibratory systems. *Journal of Sound and Vibration,* 104(1), pp. 109-125.

Tong, M., Liang, Z., Lee, G. C. (1994) An index of damping non-proportionality for discrete vibrating systems. *Journal of Sound and Vibration*, 174, pp. 37–55.

Venancio-Filho, F., Wang, Y.K., Lin, F.B., Claret, A.M. & Ferreira, W.G. (2001) Dynamic Analysis of Nonproportional Damping Structural Systems Time and Frequency Domain Methods, *Transactions*, SMiRT 16, Washington DC.

Warburton, G. B. & Soni, S. R. (1977) Errors in response calculations for non-classically damped structures. *Earthquake Engineering and Structural Dynamics*, 5, pp. 365–376.