EFFET OF THICKNESS OF DIFFERENT SHAPE MEMORY POLYMER LAYERS ON DAMPING PERFORMANCE

Abstract

Unconstrained layer damping, also known as extensional damping, is a surface damping treatment for vibration suppression. This investigation utilized tensile and dynamic mechanical analysis tests and analytical studies on polyurethane, silicone, and butyl rubbers for asymmetrical and proportioned configurations. Results showed that butyl rubber provided better results in reducing vibration amplitude in rectangular and Tubular cavities. Free layered damped samples were modeled using Solid Works, and modal analysis was conducted on the ANSYS R19 workbench.

Keywords: Free layer damping, optimization, symmetrical and asymmetrical structure.

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I. INTRODUCTION

Material damping is the energy dissipation property of a material, converting mechanical energy into thermal energy. It is produced by friction and determined by loading and unloading phases of a process. Applying damping material on the vibrating surface are the passive methods of reducing vibration, typically associated with sheet metal structure vibration. There are two types of damping treatments: Free Layer Damping (FLD) treatment and Constrained Layer Damping (CLD). Unconstrained Layer Damping is a free-layer treatment where a coating of a damping material is applied to one or both sides of a structure.

Shape memory alloys like Polyurethane rubber, Silicone rubber, and Butyl rubber were used as damping materials in this study, as they can return from a warped shape to its original shape when induced by temperature changes. The Ross-Kerwin-Ungar (RKU) equations can predict unconstrained-layer damping treatment performance, considering the case with zero constrained-layer thickness. The constrained-layer damping treatment's performance depends on the constraining layer's geometry and type. Sandwich damping treatments achieve maximum shear strain when the constraining layer is the same type and geometry as the structure being damped.

II. MODAL ANALYSIS

This study examines a FLD structure consisting of AA 6063 base metal and Epoxy Adhesive-based damping materials like polyurethane, silicone, and Butyl rubbers with 75 Shore A hardness [1].

FLD samples were created using SOLIDWORKS software, following ASTM-E756 standards. These samples were made from Polyurethane, Silicone, and Butyl rubbers with cavities in different configurations. The base plate was made of AA6063, and the layer material was glued to it using epoxy resin. The damping effect from the adhesive was ignored due to the small adhesive thickness of around 3 micron meters [2][3].

Table 1: Shape of the Free Layer Damped Specimen

Specimen	Materials	Length (mm)	Thickness (mm)	Width (mm)
Base plate	AA6063	$L_1 = 300$	$h_1 = 3$	25.4
Layer	Polyurethane, Silicone and Butyl Rubbers	$L_2 = 250$	$h_2 = 30, 40, 50$ (symmetric and asymmetric)	25.4

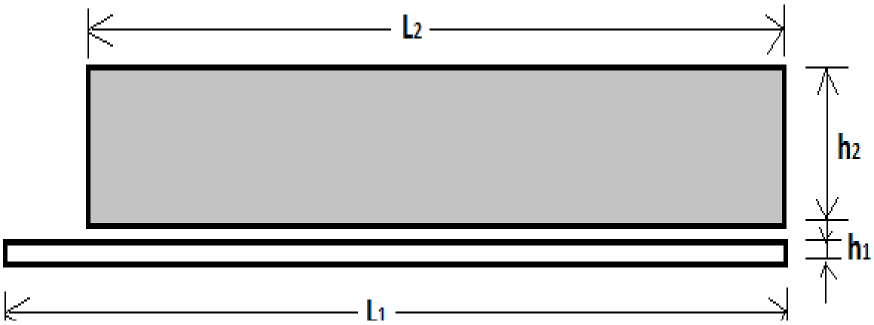

Figure 1: Basic Shape of FLD sample with no cavities

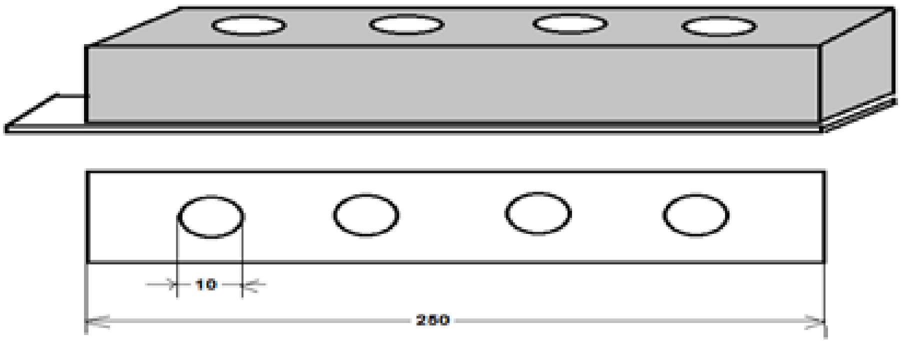

Figure 2: FLD beam with Tubular cavities of each 10mm diameter

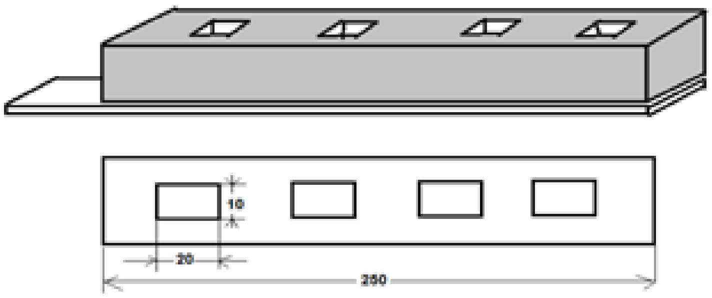

Figure 3: FLD beam with rectangular cavities of size 10mm X 20mm

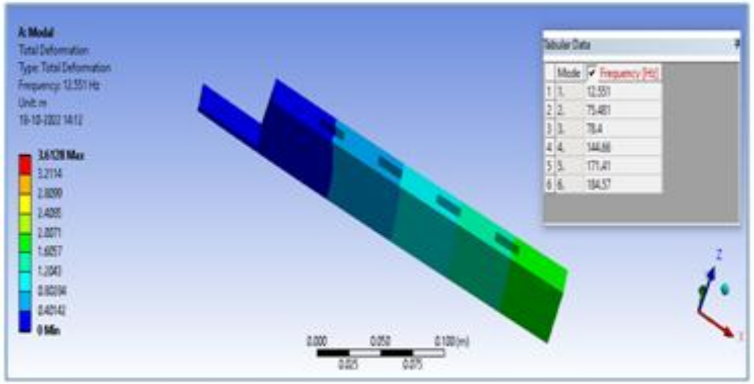

Figure 4: (a) Asymmetrical FLD beam- 30mm thick PU rubber coating with Rectangular cavities

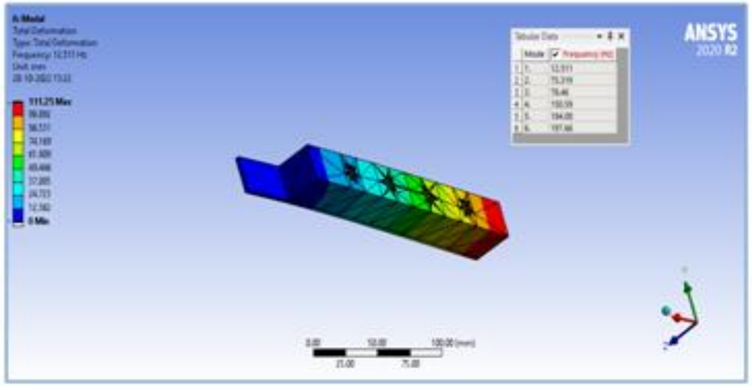

Figure 4: (b) Asymmetrical FLD beam- 30mm thick PU rubber coating with Tubular cavities

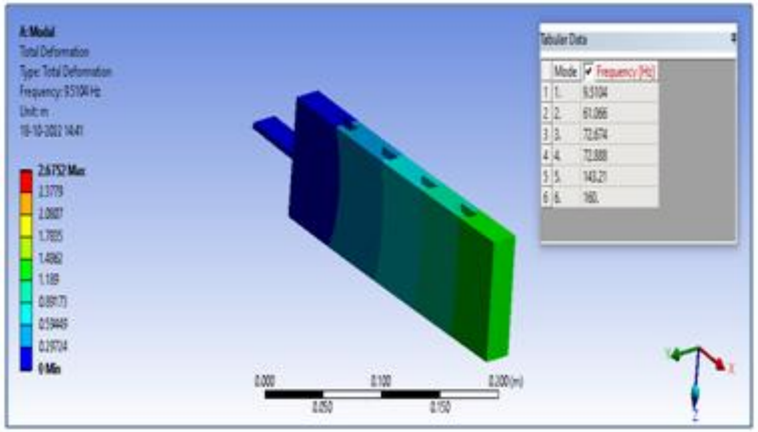

Figure 4: (c) Proportioned FLD beam- 30mm thick PU rubber coating with Rectangular cavities

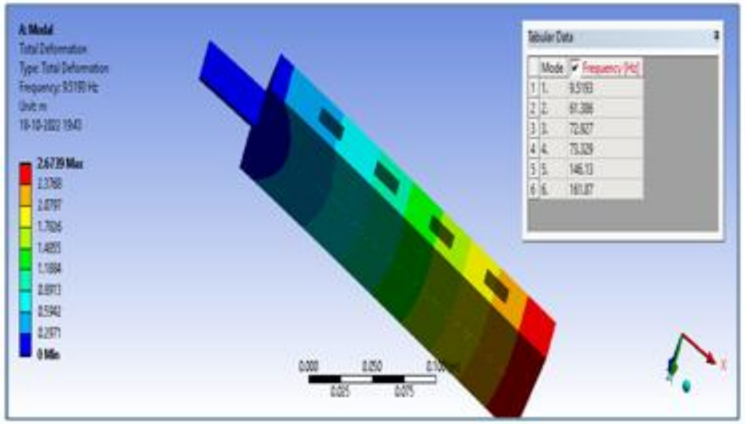

Figure 4: (d) Proportioned FLD beam- 30mm thick PU rubber coating with Tubular cavities

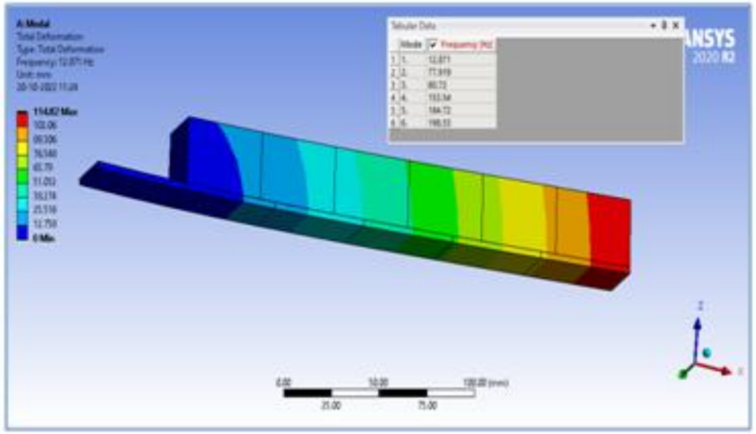

Figure 4: (e) Asymmetrical FLD beam- 30mm thick Silicone rubber coating with rectangular cavities

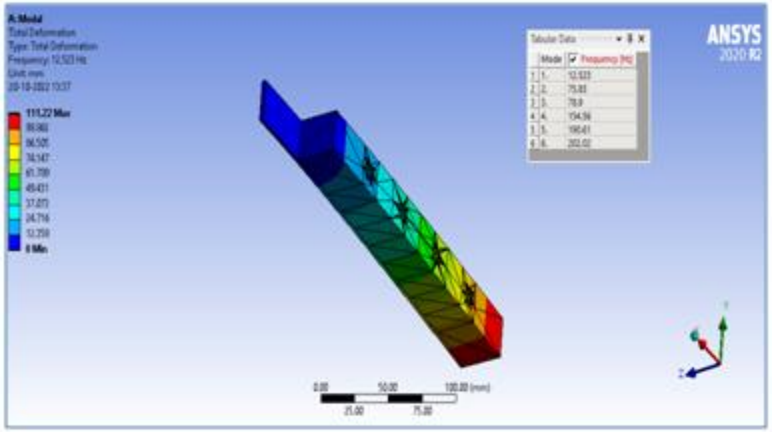

Figure 4: (f) Asymmetrical FLD beam- 30mm thick Silicone rubber coating with Tubular cavities

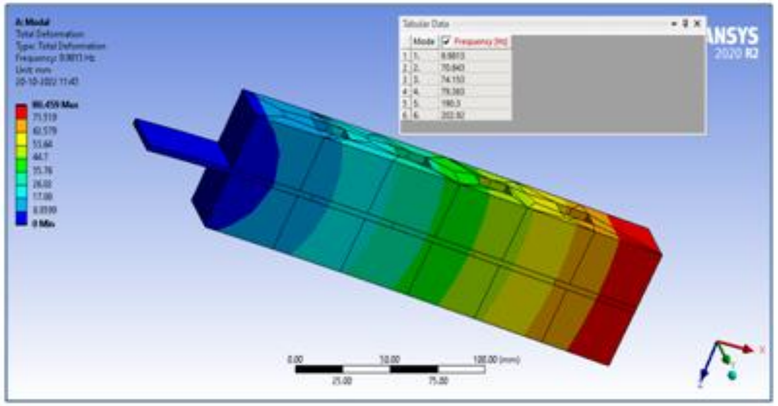

Figure 4: (g) Proportioned FLD beam- 30mm thick Butyl rubber coating with rectangular cavities

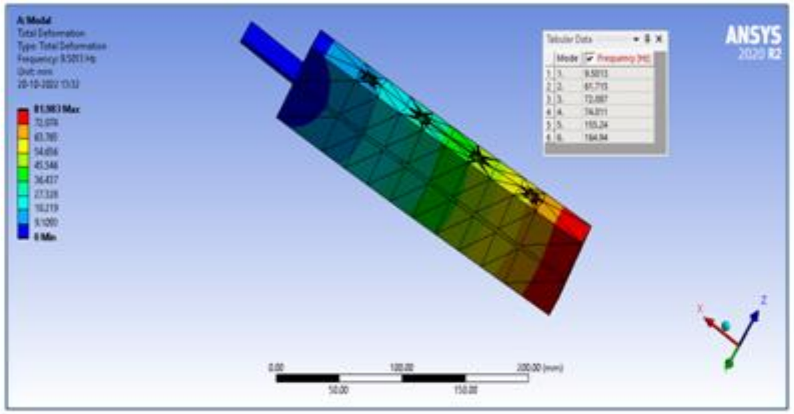

Figure 4: (h) Proportioned FLD beam- 30mm thick Silicone rubber coating with Tubular cavities

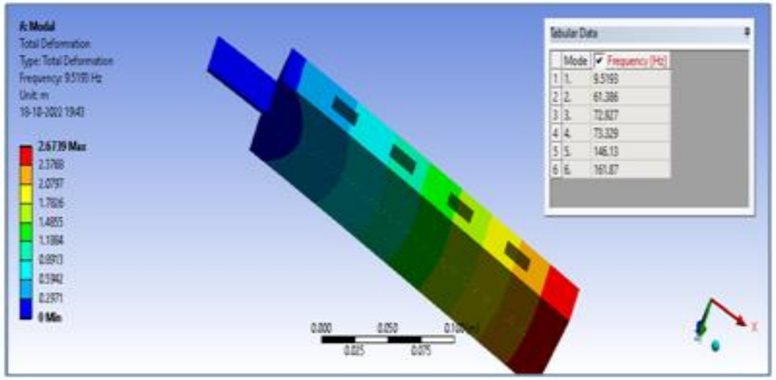

Figure 4: (i) Proportioned FLD beam- 30mm thick silicone rubber coating with rectangular cavities

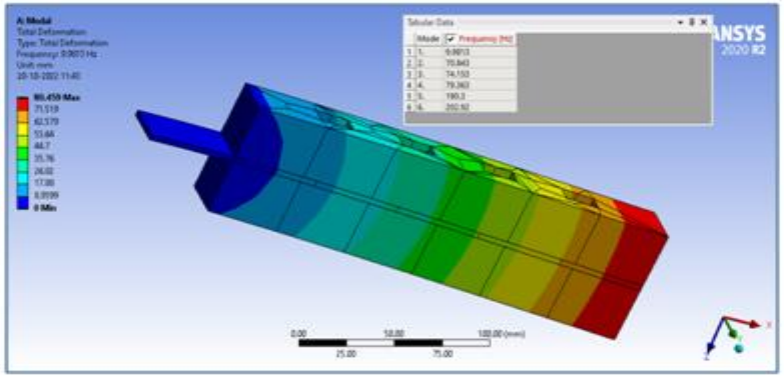

Figure 4: (j) Proportioned FLD beam- 30mm thick Butyl rubber layer with rectangular cavities

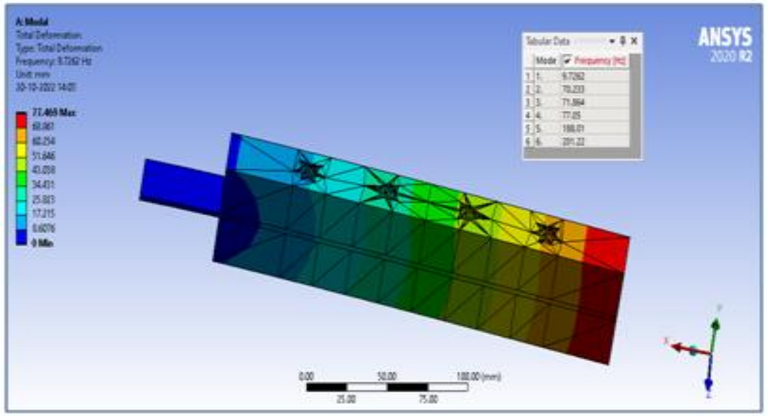

Figure 4: (k) Proportioned FLD beam- 30mm thick Butyl rubber layer with Tubular cavities

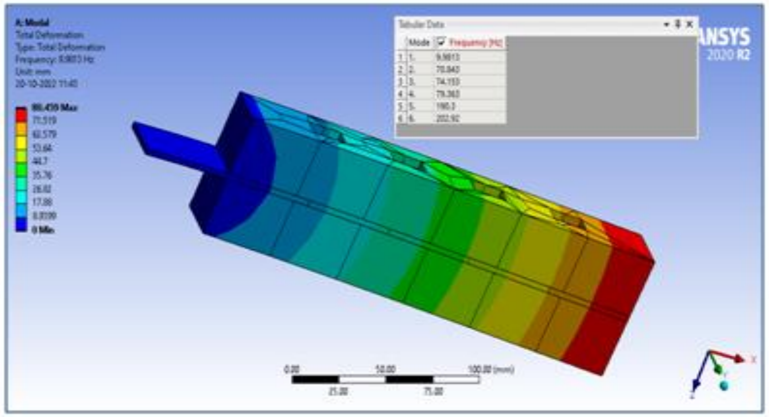

Figure 4: (l) Proportioned FLD beam- 30mm thick Butyl rubber layer with rectangular cavities

Table 2 displays natural frequency values from modal analysis of Polyurethane, Silicone, and Butyl rubber under symmetrical and unsymmetrical damping of 30, 40, and 50 mm thickness [4 to 7].

Table 2: Natural frequencies of FLD beams

S. No.	Type of SMP	Thickness (mm)	Form of Cavity	Natural Frequency with Proportioned shape (Hz)	Natural Frequency with Asymmetrical shape (Hz)
1	Polyurethane rubber	30	Rectangular	61.01	75.48
		30	Tubular	62.11	75.32
		40	Rectangular	52.73	57.19
		40	Tubular	50.08	55.97
		50	Rectangular	37.61	43.63
		50	Tubular	36.68	42.78
2	Silicone rubber	30	Rectangular	61.39	77.92
		30	Tubular	61.72	75.83
		40	Rectangular	51.85	57.85
		40	Tubular	50.59	56.62
		50	Rectangular	37.99	44.22
		50	Tubular	43.32	43.45
3	Butyl rubber	30	Rectangular	70.84	79.62
		30	Tubular	70.23	77.12
		40	Rectangular	54.98	60.77
		40	Tubular	50.79	58.96
		50	Rectangular	40.85	47.58
		50	Tubular	39.71	44.59

The above study reveals that increasing mass or lowering stiffness lowers natural frequency, while reducing mass or increasing stiffness increases it [8 to 10]. Asymmetrical configurations can operate at higher speeds without noise, wear, metal fatigue, or uneven performance. Modal analysis shows that asymmetrical configurations provide better resonant frequency response than symmetrical [11 to 13].

III. CONCLUSIONS

This study examines the damping performance of various shape memory polymers, including Polyurethane, Silicone, and Butyl rubbers. DMA tests and modal analysis are conducted using ANSYS R19 software to determine the best damping properties of the materials. Python programming is used to determine optimal values. The results show that the unsymmetrical configuration of butyl rubber with a rectangular cavity at 79.62 Hz has better results for natural frequency.

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