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THE EFFECTS OF ABSORBER ATTACHMENT LOCATION ON VIBRATION RESPONSE OF SIMPLY SUPPORTED PLATE

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ABSTRACT

Vibration analysis of thin walled structure has been an active research in engineering fields. This paper proposed to investigate the application of vibration absorber (VA) attached to the simply supported plate (SSP) in order to suppress the structural vibration. Two major factors influence on vibration reduction of plate are investigated in term of the attachment location of vibration absorber and the number of absorber applied on structural dynamic of the plate. Finite element software of ANSYS APDL was performed to measure the dynamic response of plate. The results found that the best positioning vibration absorber are at the location of 0.35 m of x-axis and 0.40 m of y-axis which can attenuate the vibration along the frequency band. Numerical result also presented that when attached multiple absorber, the vibration reduction of plate provide larger suppression to SSP which average reduction almost 80% over the frequency modes. This study conclude that right position and number of absorber can be the major contribute to suppress vibration on a plate structure more effectively.

Keywords: simply supported plate, vibration absorber, computer aided design.

INTRODUCTION

Computational prediction is one of the common technique lead to better engineering analysis. The finite element method is a numerical method that can be used for the accurate solution of complex mechanical and structural vibration problem (Zienkiewicz *et al.*, 1977), (Salleh and Zaman, 2015). In this method the actual structure is replaced by several pieces of elements, each of which is assumed to behave as a continuous structural member called a finite element. The element are assumed to be interconnected at certain points known as nodes (Singeresu S.Rao, 2005).

Finite element method solves engineering problem and it is now widely accepted by the engineering professions. Finite element method one of the relevant method that can reduce manufacturing costs, improve product quality and productt reliability (Reh *et al.*, 2006), (Zaman *et al.*, 2007). Therefore finite element method can optimized technical problem and reduce financial cost to develop a quality product (Hua and Chen 2008).

Nowadays, many engineers use finite element analysis for mechanical engineering design and optimization (Aw *et al.*, 2007). One of the popular finite element software uses is ANSYS. ANSYS is a very powerfully built finite element modelling package for numerically solving a large variety of mechanical problems (Jana and Chatterjee, 2014).

Dynamic characteristic of thin walled structure using numerical method has been widely investigated since the two decade ago (Zaman *et al.*, 2013), (Zaman *et al.*, 2014). There are numerous research investigate vibration of the plate which, (Dozio and Ricciardi, 2009) investigate analytical and numerical method of the modal characteristic of thin rectangular plate. Lin (2012) studying vibration response of a ribbed plate clamped fixed-fixed end boundary by employing a traveling wave solution. Watkins *et al.* (2010) determined modal parameter for an elastically supported plate with attached masses under impulsive loading. Krenk and Høgsberg (2014) proposed tuned mass absorber to provide damping to the flexible structure. Reza *et al.* (2010) demonstrated an active vibration control incorporating active piezoelectric actuator and self-learning control for thin rectangular plate simulated via finite difference method.

This paper demonstrated influence of difference location of dynamic vibration absorber and different number of VA attached to the SSP. Finite element method are performed using ANSYS LPDL. Numerical method are determine natural frequencies and vibration amplitude of SSP. Contribution of this study to ensure influence of different VA location and different number of VA to SSP vibrating structure.

Simply supported plate

Simply-supported plate is subjected to a point load F (x_i, y_i). The plate has a uniform thickness h, width a and length b. In this analysis, the response of a plate ω (x,y) will be determined using ANSYS in the frequency range of 10 to 500 Hz . The complete SSP model was meshed to 3016 numbers of elements and 7804 numbers of nodes. Table-1 shows the parameter of SSP models consist of I, E, ρ, ν. and the damping that is employed is the viscous damping ζ.

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Table-1. Parameters of simply supported plate.

Parameter	Description	Value	Units
A	Length	450	mm
B	Width	450	mm
H	Thickness	2	mm
I	Area moment of inertia	91.6x 10^{-9}	m^4
E	Young's modulus	2.1 x 10^2	GPa
P	Density	7.8 x 10^3	Kg/m^3
N	Poisson ratio	0.28	-
Z	Viscous damping	1.0	%

Theoretical equation of SSP

The equation of motion of a simply-supported plate can be written as in Equation.1 by (Zaman 2013):

$$EI\left(\frac{\partial^4 \omega}{\partial x^4} + 2\,\frac{\partial^2 \omega}{\partial x^2 \omega \partial y^2} + \frac{\partial^4 \omega}{\partial y^4}\right) + \rho h \frac{\partial^2 \omega}{\partial t^2} = -F(x,y,t) \qquad (1)$$

where E is the Young's modulus, I is the area moment of inersia, ρ is the density of plate and h is thickness of plate. The area moment of inersia for plate is defined in Equation. 1, where ν is the Poisson's ratio.

$$I = \frac{h^3}{12\,(1 - v^2)} \qquad (2)$$

The solution of transverse modal displacement for a plate is given by the summation of all of the individul modal amplitude responses multiplied by their mode shapes at that point:

$$\omega(x,y,t) = \sum_{m=1}^{\infty} \sum_{m=1}^{\infty} W_{mn} \text{ x } \varphi_{mn}(x,y) e^{jw_o t} \qquad (3)$$

Where W_{mn} is the modal amplitude, $\varphi_{mn}(x,y)$ is the mode shape of plate, and m and n are modal integers. The general mode shape of a simply-supported plate can be calculated with:

$$\varphi_{mn}(x,y) = 2\,\sin\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right) \qquad (4)$$

where a and b are the lenght and width of a plate, respectively. The natural frequencies of a simply-supported plate can be calculated from:

$$\omega_n = \sqrt{\frac{EI}{\rho h}\left[\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2\right]}\left(\frac{rad}{s}\right) \qquad (5)$$

By neglecting the exponential time varying term, an expression of the total response of simply-supported plate incorporating the viscous damping ζ is given as Equation. 5, respectively.

RESULT AND DISCUSSION

A simply-supported plate in Figure-1, having a dimension 0.45 x 0.45 x 0.002 m. A primary excitation point force is exerted at coordinate (0.225,0.225). Results for first seven natural frequencies of a simply supported thin plate between numerical method and mathematical method are validated in Table-2. The agreement between the ANSYS and MATLAB was good. The values of first seven frequencies are very small discrepancy for both approaches. There was found that the percentage error occurred between MATLAB and ANSYS was less than 10% which can be negligible.

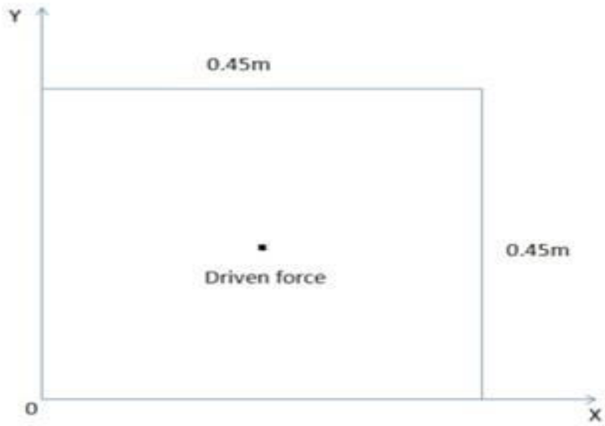

Figure-1. Simply supported plate.

Table-2. Comparison of natural frequency.

Mode	MATLAB	ANSYS	Error (%)
1	48.3	48.41	0.227
2	121.0	121.20	0.165
3	192.6	193.86	0.650
4	241.7	243.08	0.568
5	314.4	315.58	0.374
6	411.6	414.91	0.798
7	436.2	437.01	0.185

In this section describe SSP with single absorber locate at the difference coordinate. The absorber location is set randomly. There are four locations have been designated to determine the vibration reduction. Table-3 shows coordinate for SSP attached with VA. The weight of absorber was set to be 1 kg.

Table-3. Coordinate for attached DVA.

Absorber	Coordinate (m)
1	(0.2250,0.2250)
2	(0.1125, 0.1125)
3	(0.2250,0.33750)
4	(0.33750,0.4000)

Figure-2 presents the comparison of percentage reduction in difference coordinate of VA attached with SSP. Based on the graph, the first, second and third location, the percentage reduction approximately same. Meanwhile, at the location 4 shows the VA provide higher percentage reduction of vibration about 33.31%. From this

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analysis, found that the location (0.35,0.40.0) was the best location to attached VA to SSP.

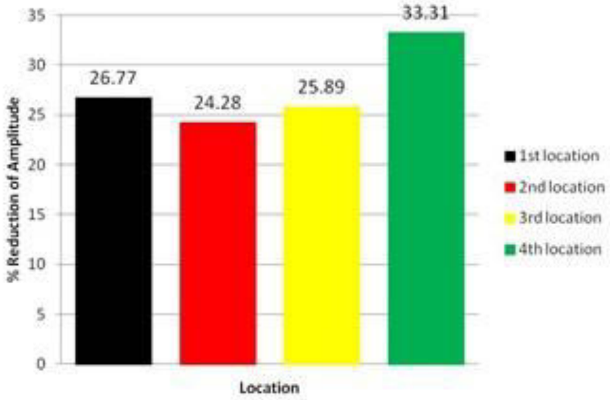
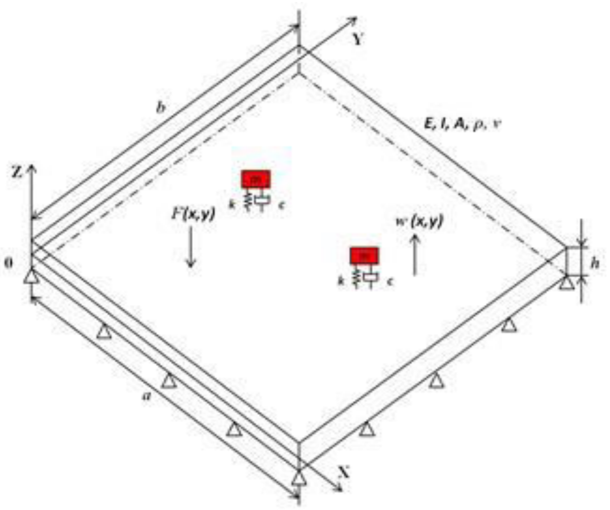
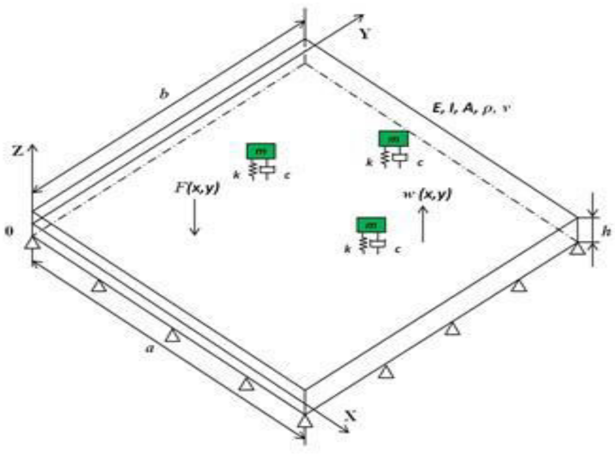


Figure-2. Average percentage reduction of different location of VA.

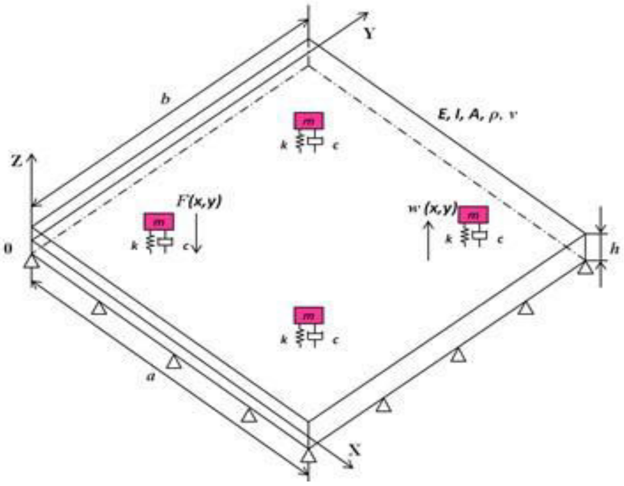
The last section was investigated the effectiveness of dual.third,fourth and fifth VA attached to SSP. Figure-3 a,b,c,d show the schematic of SSP attached with different number of VA.



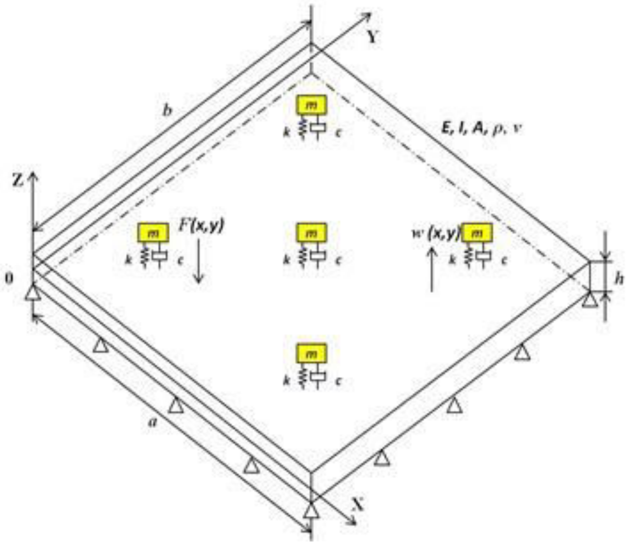
(a)



(b)



(c)



(d)

Figure-3. (a) SSP with dual VA (b) SSP with third VA (c) SSP with fourth VA (d) SSP with five VA.

Table-4 illustrated the percentage reduction of SSP attached with dual, third, fourth and fifth VA. The current result found that when using more than one absorber, the percentage reduction reduce along the frequency band. Meanwhile the most effective to reduce vibration of SSP when fifth VA attached to SSP. The percentage reduction amplitude of SSP was reduced more than 80%, along the frequency modes.

Finally, it can be concluded that multiple vibration absorber can reduce the overall global vibration compared to a single absorber. This study produced results which corroborate the findings of a great deal of the previous work in this field.

Table-4. Average percentage reduction for different location.

No. of Absorber	Mode (n^{th})	Reduction (%)	Average
2 Absorber	1^{st}	96.21	36.49
	2^{nd}	48.62	
	3^{rd}	0.75	
	4^{th}	1.41	
	5^{th}	43.14	
	6^{th}	11.95	
	7^{th}	55.39	
3 Absorber	1^{st}	96.23	50.79
	2^{nd}	91.20	
	3^{rd}	0.77	
	4^{th}	5.35	
	5^{th}	67.91	
	6^{th}	25.15	
	7^{th}	68.92	
4 Absorber	1^{st}	99.48	73.63
	2^{nd}	90.86	
	3^{rd}	86.10	
	4^{th}	80.24	
	5^{th}	74.74	
	6^{th}	-9.82	
	7^{th}	93.83	
5 Absorber	1^{st}	99.48	80.52
	2^{nd}	95.60	
	3^{rd}	92.72	
	4^{th}	91.48	
	5^{th}	73.75	
	6^{th}	59.17	
	7^{th}	51.44	

CONCLUSIONS

Studies have been analyzed the vibration reduction of SSP attached with different location of absorber and different number of absorber attached to SSP. Dynamic characteristic and modal parameter of SSP was performed using ANSYS LPDL. This paper has found that generally SSP by employing first second and third location, the vibration reduction almost same there is only a small discrepancy in amplitude value. Meanwhile, at the location 4 (0.35,0.40,0) shows the vibration absorber provide higher suppression about 33.31% percentage reduction rather than other location.

The second major finding was that the multiple absorber provides better attenuation rather than single absorber. The most obvious finding to emerge from this study is that location of the absorber and number of absorber play important roles on vibration suppression of structure.

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