Proceedings of Mechanical Engineering Research Day 2016, pp. 200-201, March 2016

Radiation efficiency of single beam-stiffened plate

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Keywords: Radiation efficiency; beam-stiffened; sound radiation

ABSTRACT – Beam-stiffened method had been used widely in controlling noise problem. However the effect of this technique has not been fully studied and may cause undesired results. This paper studies how different point forces location affect the sound radiation efficiency from beam-stiffened plate. Hybrid mathematical model which comprised of a semi-analytical model and FE model is used to conduct this study. Radiation efficiency by 8 points force location and average radiation efficiency over 8 points force location from single beam-stiffened plate are presented. Besides, range of radiation efficiency variation using 10 and 90 percentile is also presented.

1. INTRODUCTION

Beam-stiffening technique had been used widely in controlling noise problem but it effects on sound radiation have not been fully studied and might lead to undesired noise radiation [1].

Study on sound radiation from beam-stiffened plate was started by Maidanik proposing a statistical method in estimating radiation efficiency of a ribbed panel, followed by Lyon who studied the sound power from an infinite beam attached to an infinite thin plate [2,3]. In later years, several works were published in estimating the sound radiation from beam-stiffened plate structure such as using Fast Fourier Transform and applying the Rayleigh-Ritz formula [4,5].

This paper studies on how different force positions affect by the sound radiation efficiency of beam-stiffened plate using hybrid mathematical modeling.

2. METHODOLOGY

2.1 Hybrid mathematical modeling

In this paper, hybrid mathematical model by Putra et.al is used to conduct the study on sound radiation efficiency of beam-stiffened plate. This mathematical model combines the velocities across the plate from FE model with semi-analytical model. The result from FE will be used with the semi-analytical to calculate the radiated sound pressure through Rayleigh integral [5]. The overview of this mathematical model is shown in Figure 1.

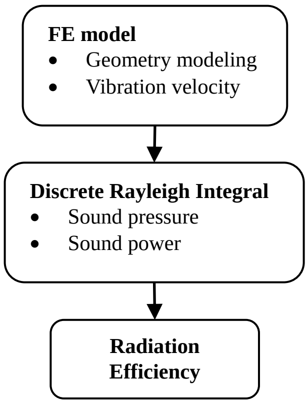

Figure 1 Overview of hybrid mathematical model.

2.2 Governing equation

Consider a rectangular plate lying on xy-plane and excited by a harmonic force. The radiated sound pressure from the plate at the far-field at distance, r is given by [6]

$$p(r)=\frac{jk\rho c}{2\pi}\int_s v(x,y)\frac{e^{-jkr}}{r}dS \tag{1}$$

Where p is the sound pressure, e^{-jkr}/r is the Green's function, v is the velocity of the plate, ρ is the air density, c is the speed of the sound, k is the acoustic wave number, S is the area of the plate and r is the distance from the plate velocity to the pressure at the air

Assume the plate consists of elementary discrete sources that are vibrating independently, Eq. (1) can be discretized and is written as

$$p(r)=\frac{jk\rho c}{2\pi}\sum_{n=1}^{N}v_n(x,y)\frac{e^{-jkr}}{r}dS \tag{2}$$

where v_n is the velocity at the n-th element of the plate. This is obtained from the FE model to be the input back in Eq. (2). The radiated sound is given by

$$W=\frac{1}{2}\mathrm{Re}\{\sum p_n v_n(x,y)\}dS \tag{3}$$

and the radiation efficiency, σ of the plate can be obtained by

$$\sigma = \frac{W}{\frac{1}{2}\rho c S \left\langle \left| v_n^2 \right| \right\rangle} \quad (4)$$

Where $\left\langle \left| v_n^2 \right| \right\rangle$ is the spatially average squared velocity of the plate.

2.3 Average radiation efficiency

In this study, single beam-stiffened plate as shown in Figure 2 having rectangular aluminum base plate with dimension $0.5\times0.6\times0.003$ m with 0.1 damping is considered. The stiffener dimension is $0.02\times0.5\times0.01$ m. The Young modulus, density, and Poisson ratio are 7.1×10^{10} Pa, 2700 kg/ m^3 and 0.3, respectively. The beam-stiffened plates are excited by 8 points force. The locations of the 8 points force are chosen based on Putra et.al as shown in the Figure 3 [7].

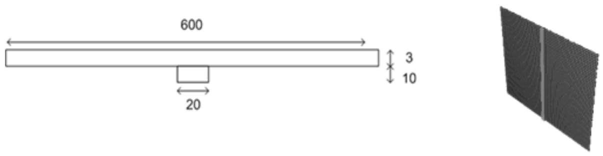

Figure 2 Configuration and dimension of single beam-stiffened plate in mm.

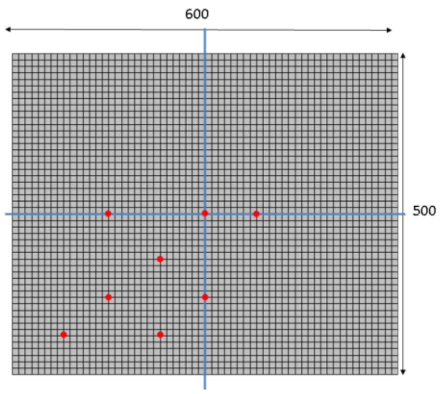

Figure 3 Positions of point force on the plate surface.

3. RESULTS AND DISCUSSION

Figure 4 shows the distribution of radiation efficiency and average radiation efficiency over 8 points force. It can be noticed that at 210 Hz, there is a high curve. This high curve is the result of exciting the plate at the center of the plate which does not excite the even mode. Besides, other curves dip at 190 Hz and this is due to (2, 1) mode [7].

Figure 5 shows the range of radiation efficiency using 10 and 90 percentile and average radiation efficiency in one third octave bands. In the monopole region (1-150 Hz) and above critical frequency region (>4000 Hz), radiation efficiency is seen to be unaffected significantly due to force positions. However, it can be seen that force points location affect the radiation efficiency the most in the corner mode region (150 Hz-4000Hz).

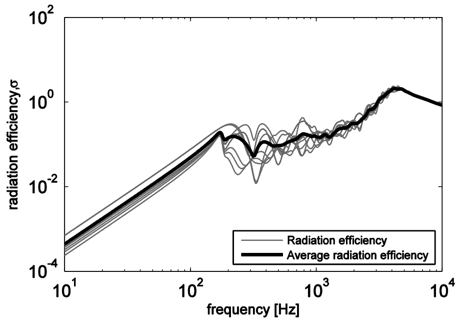

Figure 4 Distribution of radiation efficiency (thin) and average radiation efficiency (thick) over 8 points force locations.

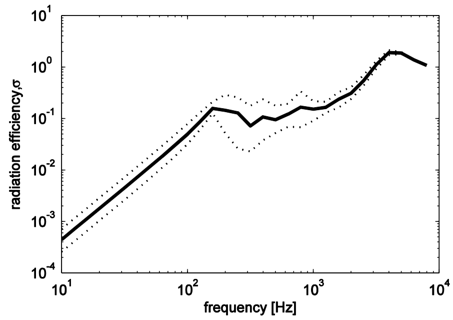

Figure 5 Range of radiation efficiency using 10/90 percentile (dotted) and average radiation efficiency (thick) in one third octave bands.

4. CONCLUSION

Radiation efficiency and average radiation efficiency of single beam-stiffened over 8 points force location has been presented. The position of the point force acted on the plate affect the radiation efficiency in the corner mode region (150-1000 Hz) the most.

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