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# Radiation efficiency of beam-stiffened plate: experimental setup and preliminary results

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**Abstract**

Beam stiffening technique has been widely used in engineering application to minimize the vibration of structures, to increase its loading capacity and to prevent the structure from buckling. However, study on the sound radiation from the beam stiffened plate is still lacking. This paper mainly presents the experimental setup to measure the radiation efficiency of three-beam and the five-beam stiffened plates. The treatment for the test plate is discussed. Reciprocity technique was employed to measure the sound power. In general, the measured results for the acoustic power show good agreement with those from the proposed mathematical model. Measured radiation efficiencies overestimate the simulation results of high frequencies due to error in the mobility measurement.



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*Keywords:* Radiation Efficiency; Beam-stiffened Plate; Acoustic

## 1. Introduction

Beam stiffening is a general technique used to minimize the vibration of structures, to increase its loading capacity and to prevent the structure from buckling [1]. The application of this technique can be seen in the aircraft fuselages or ship hulls. Despite wide application of this treatment, the study on the effect of beam-stiffening technique on sound radiation is not fully covered. Over the years, researchers had proposed several methods to predict the sound radiation from beam-stiffened plates. Generally, they are the numerical methods such as finite element method (FEM) [2], boundary element method (BEM) [3], statistical energy analysis (SEA) [4] as well as the analytical method, for example the Rayleigh-Ritz energy method [5]. The numerical methods gain more popularity due to its flexibility. However, experimental study on the sound radiation from a beam-stiffened plate is also lacking. This experimental setup is thus discussed in this paper and preliminary results for the measured radiation efficiency are presented. For clarity, mathematical model to estimate the radiation efficiency is first highlighted and is then followed by the experimental setup and results.

## 2. Simulation

### 2.1. Mathematical Model

The mathematical model proposed by Putra [6] was adopted to calculate the radiation efficiency of the beam-stiffened plate. In general, this model calculates radiation efficiency by obtaining the discrete surface velocities of the plate from the FE model and these are then used to calculate the far field sound pressure using the discrete Rayleigh integral and finally the radiated sound power can be obtained. Fig 1 show the general flow of the mathematical model. Details of the governing equation can be referred in [6].



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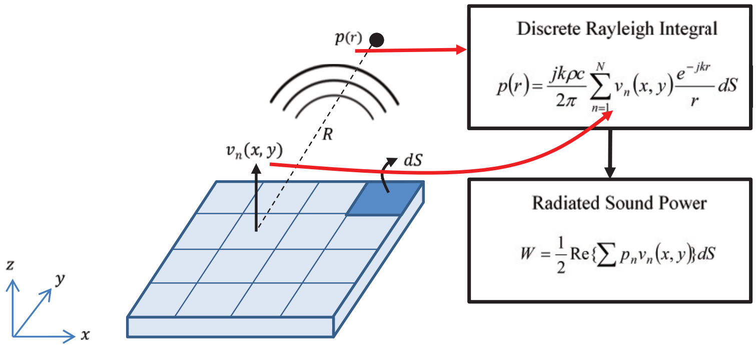


**Fig. 1.** Diagram of the proposed model to calculate the sound power from a vibrating plate.

### 2.2. Finite Element model

Abaqus 6.10 was employed to calculate the surface velocity of the beam-stiffened plates. The stiffened structures were modelled as aluminium plates with dimensions of 0.31×0.21×0.001 m. The beam stiffener is also made of aluminium having dimensions of 0.02×0.21×0.003 m. Both the beam and the plate have the same material properties of Young modulus of $7.1\times10^{10}$ N/m$^2$, Poisson ratio of 0.3, and damping ratio of 0.01 and density of 2700 kg /m$^3$.

Here, the stiffened-plate was simulated with the three and five beam stiffeners. In the FE model with the plate was modelled as thin shell and the beam was modelled as wire. The beams were then attached on the plate with contact feature. The beam-stiffened plate was meshed with 0.01 resolution per meter and thus resulted in total of 600 elements for the plate and 20 elements for each stiffener. All edges of the plate and the end of the beams were assigned with clamped boundary condition. The frequency resolution is 100 point per decade from 10 Hz to 8 kHz. The excitation point is located off-set the center of the plate to generate optimum modes of vibration. The velocity across the plate are recorded to obtain the mobility of the panel

The first three natural frequencies for the unstiffened plate, three-beam and five-beam stiffened plates are listed in Table 1. It can be seen that as the number of the stiffener increases the natural frequencies shift to higher frequencies as the result of the increasing stiffness of the plate

**Table 1.** First three natural frequencies of unstiffened plate, three-beam stiffened plate and five-beam stiffened plate

| Mode | Natural Frequency (Hz) | | |
|---|---|---|---|
| | Flat | 3 Beams | 5 Beams |
| 1 | 154.6 | 433.3 | 471.3 |
| 2 | 241.6 | 483.7 | 514.6 |
| 3 | 381.2 | 547.6 | 588.9 |

## 3. Experimental work

### 3.1. Mobility measurement

A rectangular aluminium plate with dimensions the same as the FE model was used as the base plate in the experiment. A customized frame as shown in Fig. 2(a) was used to clamp the plate as well as the tips of the stiffening beam stiffeners. Beams with square cut sections were used to clamp the tips of the stiffeners. It is important to ensure that the edges of the plate are clamped completely as failure to do so will not satisfy the clamped boundary condition. Thus holes were drilled at the edge of the plate and screws were used to hold the plate tightly against the frame. Two types of adhesive materials were used to attach the beam stiffener on the surface of the plate, namely the polyvinyl ester and ethyl cyanoacrylate. Both of the adhesive materials were chosen because it can be easily obtained from the market and can be used for other general purposes.

Vibration response of the plate is presented as the mobility. For this purpose, an impulse hammer was used to provide and to record the injected force to the plate and a miniature accelerometer was used to record the response of the plate. Eleven response points were located across the panel and these were ensured that no points are repeated due to symmetry as shown in Fig 3. The