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# Study on the Effect of the Impact Location and the Type of Hammer Tip on the Frequency Response Function (FRF) in **Experimental Modal Analysis of Rectangular Plates**

# **K D Mali and P M Singru**

Department of Mechanical Engineering, BITS, Pilani, K. K. Birla Goa Campus, NH17B Bypass Road, Zuarinagar, Sancoale, Goa, India, 403726

Corresponding author E-mail: kiranm@goa.bits-pilani.ac.in

Abstract. In this work effect of the impact location and the type of hammer tip on the frequency response function (FRF) is studied. Experimental modal analysis of rectangular plates is carried out for this purpose by using impact hammer, accelerometer and fast Fourier transform (FFT) analyzer. It is observed that the impulse hammer hit location has, no effect on the eigenfrequency, yet a difference in amplitude of the eigenfrequencies is obtained. The effect of the hammer tip on the pulse and the force spectrum is studied for three types of tips metal, plastic and rubber. A solid rectangular plate was excited by using these tips one by one in three different tests. It is observed that for present experimental set up plastic tip excites the useful frequency range.

## **1. Introduction**

While performing impact testing, resulting frequency response function may have considerable effect of the input impact location [1]. For this study, solid rectangular plate is divided in to a grid of 10 x 10 points with boundary condition clamped all edges. Four nodes were considered for accelerometers and for each of the accelerometer position; excitation is given at the remaining three nodes. The experimentation is conducted by using, roving excitation method i. e. excitation is roving and the response is fixed. The transfer function of every impact location was calculated by the spectrum analyzer.

The selection of the hammer tip can also have a considerable effect on the FRF acquired [1]. The impulse force excites all the resonances within its useful frequency range. The frequencies contained in the energy applied to the structure depend upon the stiffness of the surfaces contacting and, also to some extent on the hammer mass. Shape of the force pulse determines the frequency content but the shape of the force pulse is affected by stiffness of the contacting surfaces. Most of the times it may not be possible to alter the stiffness of the test object; therefore frequency content can be controlled by varying the stiffness of the hammer tip [2, 3].

## 2. Experimentation

Experimentation was carried with the help of two channel FFT analyzer, impact hammer and accelerometer [4]. Figure 2 shows the experimental set up used for the testing. The assembly of the fixture plates with the test specimen placed centrally between them was clamped firmly to the rigid foundation of a machine tool. For clamping the test fixture firmly to the rigid foundation, bolt heads were inserted in the horizontal **T** slots of foundation and were passed through the holes provided along

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the circumference of the fixture plates. Hexagonal nuts were tightened over the bolts for firmly holding the test fixture. Uniform clamping pressure was applied at all the bolts by using torque wrench [5]. Uniform torque of magnitude 28 N/m was applied to all the bolts for tightening [6]. Readings were taken by fixed response method. The final spectrum for each reading was obtained from eight impacts at each sampling point. The weight of the accelerometer (Model: 352C68, PCB Co., USA) is 2 g. The approximate weight of the specimen is 467g. Thus accelerometer dynamic mass is much less compared to the plate so influence of the accelerometer mass on the dynamic behaviour of the specimen is neglected in the present study [5]. From literature it is found that the mass of the accelerometer should be less than one-tenth from the effective mass of structure to which it is attached [5, 7, 8].

## 2.1. Effect of the Impact Location

Effect of the impact location on the resulting frequency response function (FRF) is discussed in this section. For this study, solid rectangular plate is divided in to a grid of 10 x 10 points as shown in figure 1. Top diagonally symmetric portion with encircled points which has 15 node points is considered for study as shown in figure 1 & 2. Points 1, 5, 12 and 15 were chosen for accelerometer positions and for each of the accelerometer position; excitation was given at the remaining three nodes. For example if accelerometer is at position 1 then excitation was given at the points 5, 12 and 15. The following two aspects were focused for the discussion:

- [1] Effect on the relative amplitude of the first three frequencies for the different hammer locations
- [2] Effect on the relative amplitude of the first three frequencies for the different accelerometer locations



Figure 1. Layout of the experimental grid points on the plate.

The experimentation was conducted for analyzing above two aspects by using, roving excitation method i. e. excitation is roving and the response is fixed. The transfer function of every impact location was calculated by the spectrum analyzer (Spider-81 vibration controller system, Crystal Instruments) and was recorded for the eight impacts to obtain the final spectrum for every impact location. Similar experiments were repeated for each point 1,5,12, and 15. Final results of the FRF for each point for the particular accelerometer location are given in figure 3.



Figure 2. The experimental set up and plate specimen with grid points.

## 2.2. Effect of the Impact Hammer Tip.

The effect of the hammer tip on the pulse and the force spectrum is illustrated in figure 4 and figure 5 respectively. The effect is studied for three types of tips metal, plastic and rubber. A solid rectangular plate was excited by using these tips one by one in three different tests. It is observed from the comparison of the pulse durations that the pulse duration for rubber tip is more whereas for metal tip and the plastic tip pulse duration shows small variation i.e. slightly more for plastic tip.

## 3. Result and Discussion

#### 3.1. Effect of the impact location

The FRF plots are obtained for the accelerometer locations at the point 1, 5, 12 and 15 and are given in figure 3. For each accelerometer location the impact points are chosen at the three remaining nodes. Thus for the each accelerometer location three FRF's are obtained and are superposed as shown in figure 3. These cases are presented here because effect of the accelerometer and the impact location on the amplitude of the resonance peaks in the FRF, is a very common problem during the impact testing.

From the FRF's obtained it can be observed that, for a particular accelerometer location amplitude of the resonance peak depends on the impact location. In impact test modal analysis to get all the modes of interest one should include sufficient points. If enough response points are not included in measurement or the excitation point has not been chosen carefully, then chances of not getting excited a particular mode are there. This can be observed for the accelerometer location at point 12 where the second frequency peak is not distinctive. This may be because of a node at point 12 for mode 2. Thus by including more number of excitation points at times it may sufficiently describe modes of the interest.

It is observed that as the impact hammer excitation location moves towards an accelerometer the response level tend to increase, or a accelerometer moves towards the impact hammer excitation location, and tend to decrease as the excitation location and the accelerometer move away from each other. In the following figures it appears that the impulse hammer hit location has, no effect on the eigenfrequency, yet a difference in amplitude of the eigenfrequencies is observed. Mode shape for each resonant frequency is described by the amplitude of the peak associated at each location. The results indicate that for the first mode and the third mode, the fixed plate has maximum deflection at the middle.

#### 3.2. Effect of the impact hammer tip

From figure 5 it can be seen that for rubber tip all the modes of interest will not be excited adequately as the tip is too soft. Due to softness of tip the input power spectrum does not excite all of the frequency range of interest. Further it can be observed from input power spectrum of metal tip that pulse duration is shorter for harder tip, and thus this pulse has higher frequency content [9]. If hammer tip used is too

hard then it may impart energy to the structure beyond the interest range of frequency, also it may overload the response [9].



Figure 3. FRF's for different accelerometer locations on the plate.



Figure 4. Force pulse with the different impact tips on the impact hammer



Figure 5. Force spectrums with the different impact tips on the impact hammer

## 4. Conclusion

1. The FRF plots are obtained for the accelerometer locations at the point 1, 5, 12 and 15 and are given in figure 3. It can be noted that when the hammer position is at point-12 (centre of the plate) and the accelerometer location is varied, the overall amplitude of the FRF is maximum for the first and third resonant peak.

2. Also a common observation for all the roving locations is that for any particular FRF, the relative amplitude of the first three frequencies is as follows: 3st Frequency > 1st Frequency > 2nd Frequency.

3. When the accelerometer is kept at Point-12, the FRF is almost the same irrespective of the hammer location.

4. More modes were excited when the impact was given at the corner positions compared to when it was given at the center position (Point-12).

5. Due to inconsistency in impacting the same location for each measurement or inconsistency in maintaining constant angle of strike amplitudes of the resonant peak vary.

6. For a single measurement made up of average readings, well controlled precise impact excitation consistency need to be maintained.

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