THE ASSESSMENT OF COUPLING BETWEEN TWO CONNECTED PLATES IN A SEA SENSE

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Abstract. *The Statistical Energy Analysis (SEA) is a framework that has been developed to provide an estimate for the distribution of vibrational enrgy within a particular subsystem. The SEA formulation can be exact for one unique system, but, if the modal overlap is to small, the coupling loss factors are to sensitive to small changes in the physical parameters. In this paper, the strength of coupling was assessed using experiments with two coupled plates. The parameter Cs was calculated. It is defined as the ratio between the approximate duration of the signal and the time delay. Experiments were performed on two connected plates which are made of similar materials, have the same thickness but irregular shapes. The plates were coupled by removable straps. The strength of coupling was assessed for different frequency bands and configurations of coupling by using a varying number of straps.*

Keywords*: Statistical Energy Analysis, Coupling, Energy*

1. INTRODUCTION

There have been many studies on the development of models to measure the strength of coupling between subsystems using the Statistical energy Analysis. The time delay to the peak of the kinetic energy has been used as an indicator of the strength of coupling. This indicator proposed by Langley (1990) showed to be a good indicator for the strength of coupling as it is measureable on any system. However, there are a couple of disadvantages on using it. First, the value of this parameter depends on the total duration of the signal on the time domain. In other words, it means that it is related to the total loss factor of the subsystem considered. Second, it is also sensitive to the coincidence of the modal natural frequencies of the uncoupled systems.

Recently, James and Fahy (2000) derived an indicator of strength of coupling, denoted by Cs. It was defined as the ratio of the time delay to the peak of the temporal moving-average of kinetic energy of the indirectly excited subsystem to the approximate duration of the signal. This general parameter appears to be a good indicator which allows one to assess the strength of coupling between subsystems efficiently. It is a non-dimensional parameter based on the temporal moving average of kinetic energy. According to Fahy and James (2000), it indicates the strength of coupling independently of what system is being considered. It was shown that if Cs > 0.07, the subsystems could be considered weakly coupled. Nevertheless, theoretical studies have show that Cs is not altered at resonance frequencies, but it is still sensitive to the coincidence of the subsystems modal natural frequencies.

A particular situation occurs if the uncoupled resonance frequencies are significantly apart from each other. In this case, the value obtained for Cs is fairly small whereas the subsystems are weakly coupled. In SEA, if there is weak coupling, the interaction between modes of connected subsystems can be represented on a mode-to-mode basis.

The main aim of this initial work was to describe the measurement the parameter Cs and assess the practicability of the experimental procedure for acquiring test data.

2. SET UP FOR THE EXPERIMENTAL TESTS

The tests were performed in order to measure the strength of coupling as a function of the number of straps. Experimental tests were made on two rectangular plates made of steel. The plate area is equal to 0.7 x 0.8 m^2. Each plate has a thickness of 0.005m. The strength of coupling was verified by varying the number of straps. Some damping material was attached to the plates in order to reduce the size of the time window used in order to guarantee good accuracy on the impulse response measurements.

The measurement of damping for the plates was based on the Power Modulation Technique (Ruivo and Fahy, 1996 and Ming, 2005). A force was applied by an instrumented hammer on four different points on each plate. For each point excitation, the accelerations were measured at seven points on each plate. The frequency resolution used was equal to 0.2 Hz. The force x acceleration coherence was close to unity over most of the frequency range. The input powers were estimated using the imaginary part of the force-acceleration cross-spectrum.

The two plates were hung from a concrete frame (see Figure 1). The plate on the left was excited by using a instrumented hammer. An accelerometer was attached to the plate on the right in seven different positions. Thus, a space-averaged value for the Cs parameter was obtained.

The signal coming from the accelerometer was first filtered using a band-pass filter. Secondly, portable data acquisition equipment was used and the filtered signal was analyzed. The band-pass filtered impulse response was derived using the inverse Fourier transform of the ratio of the band-pass filtered acceleration response and the input force. The signal was then squared and its temporal moving-average is derived with a period approximately 20 times greater than that corresponding to the lower frequency of the bandwidth considered on the analysis.

The time-interval used for the moving average corresponded to the period related to the first natural frequency of the plate. Thus, the period T was chosen to be approximately 0.1. If it is too long, the temporal evolution of the signal is suppressed. On the other hand, if T is to short, there might be excessive oscillation on the calculated temporal moving-average curve. The definition of the temporal moving-average of a function $f(t)$ is given by

$$\left\langle f(t)\right\rangle_T = \frac{1}{T}\int_{-\infty}^{+\infty} f(\tau)g(t-\tau)d\tau$$

where $g(\tau)$ = 1 for $0 < \tau < T$ and $g(\tau)$ = 0 otherwise.

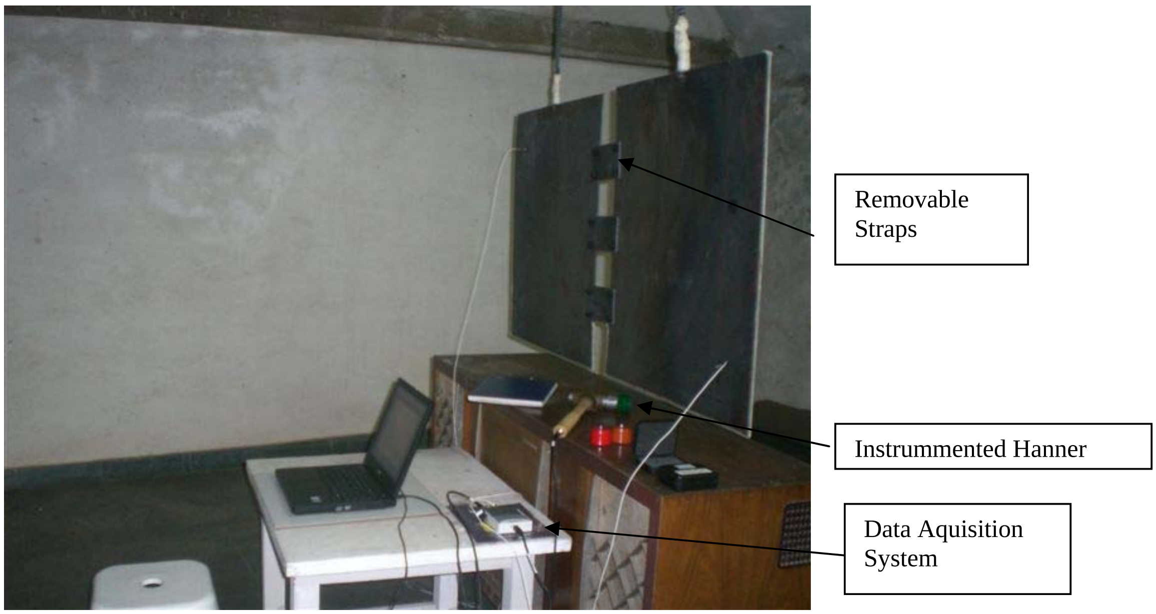

Figure 1: Set-up for the experimental tests

The Cs parameter was derived from the moving-average of the kinetic energy.
Three different plate configurations were considered (one, two and three straps) for the frequency range 0-1000 Hz.
The critical frequency and the modal density of each plate was approximately 2.392 Hz and 0.04 mode/Hz.
According to James and Fahy (2000), the parameter Cs is defined as:

$$C_s = \frac{b_1}{b_1 + b_2} \tag{1}$$

where b_1 and b_2 are related to the shape of the time-moving average of the kinetic energy of the coupled plates (James and Fahy, 2000).

The signal is considered to be negligible if its value is less than 10% of it s maximum value (see Figure 2). Besides, Cs is a non-dimensional parameter which is independent of the group speed.

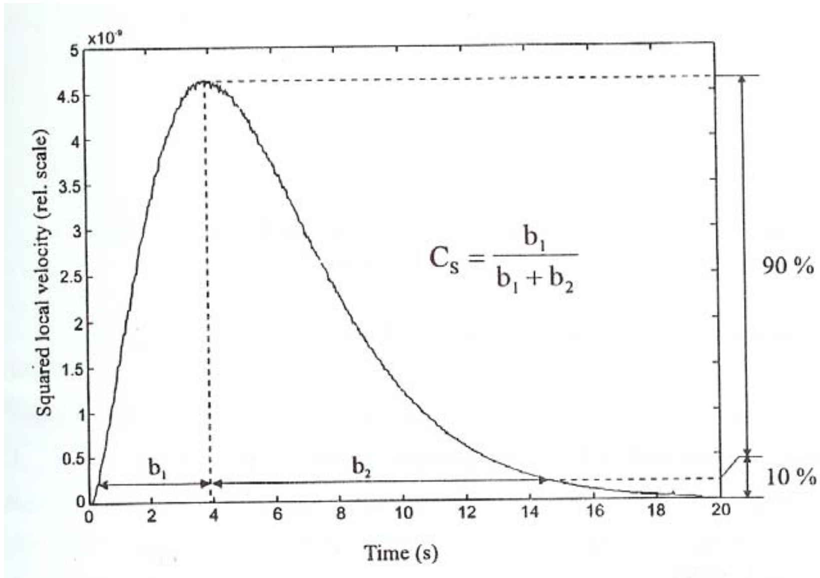

Figure 2: The parameter Cs is related to the shape of the time-moving average of the kinetic energy

3. RESULTS

Figures below show the magnitude of the kinetic energy and its temporal moving average. The space-averaged kinetic energy density was estimated from velocities evaluated at five discrete points. The frequency band considered was 0-5000 Hz. The temporal moving average of the kinetic energy acts as a filter which removes the oscillatory feature of the signal.

Figure 3, 4 and 5 shows the results for the indirectly excited subsystem for 1, 2 and 3 straps respectively. It is shown that the kinetic energy decrease more rapidly as the number of straps increases. It might be related to the increase of coupling between the source and receiving plate, which was represented by the Cs parameter in a SEA sense.

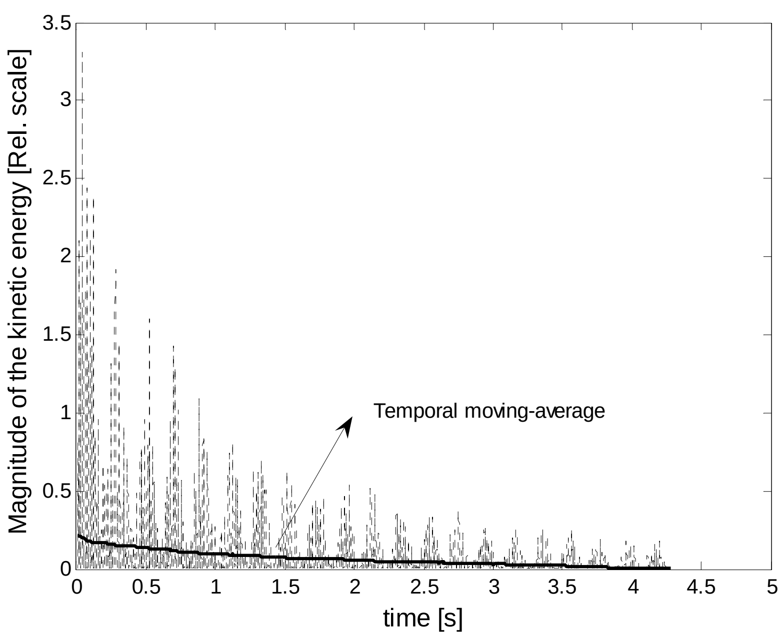

Figure 3: Space-averaged magnitude of the kinetic energy on the receiving plate for a 1-strap connection.

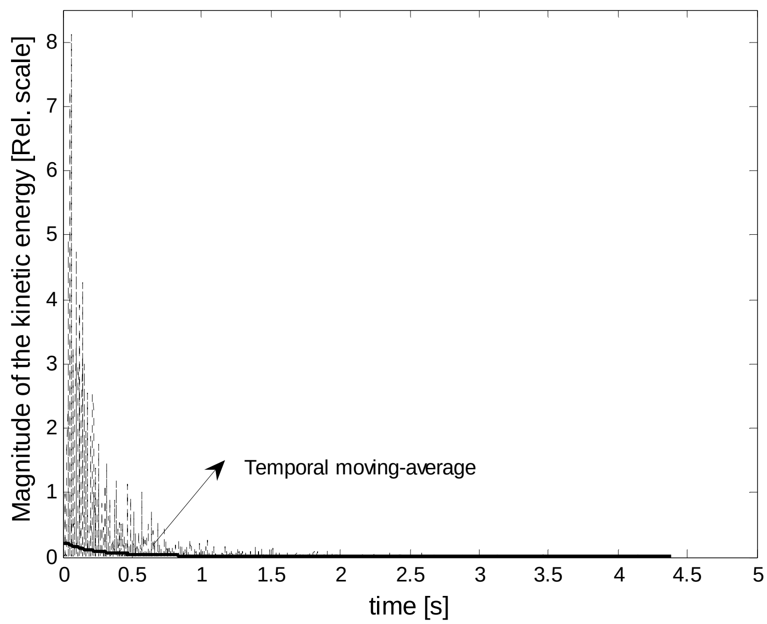

Figure 4: Space-averaged magnitude of the kinetic energy on the receiving for a 2-strap connection.

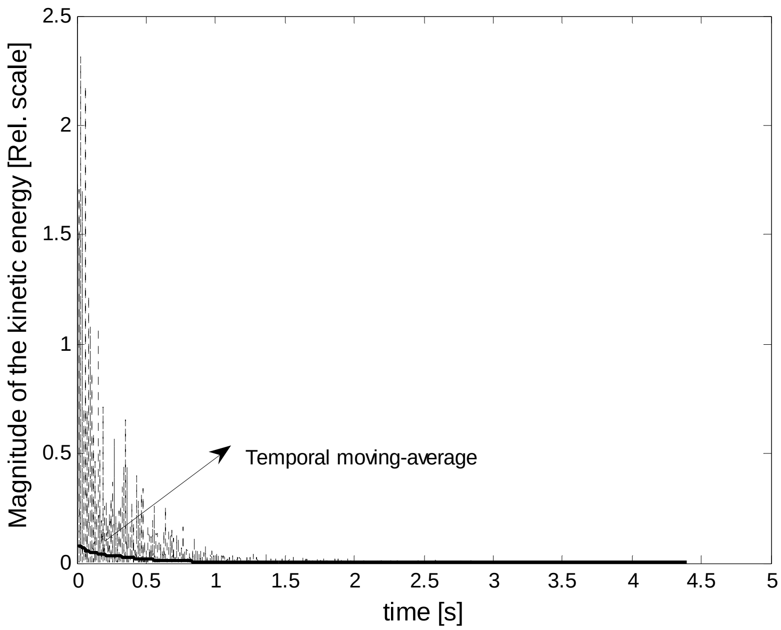

Figure 5: Space-averaged magnitude of the kinetic energy on the receiving for a 3-strap connection.

The Cs factors were derived for the three cases – 1, 2 and 3 straps. Table 1 below presents the space-averaged value of Cs derived from the measurements. They are shown on the table below:

Table 1. Variation of the Cs values obtained from the experimental results with the number of straps

Number of straps	Cs
1	0.0155
2	0.0106
3	0.0085

It was observed that the values of Cs decreased as the number of straps increased. In most cases the values of Cs decrease as the number of straps is increased. It is well-known that a significant difference should be observed between the temporal evolution of the averaged kinetic energy of both source and receiving plates. However, the curve features show on the figures above indicates strong coupling between both plates. The temporal-moving average of the kinetic energy is like a filter which shows only the general characteristics of the results in the time domain. According to Fahy and James (2000), two subsystems should be considered as weakly coupled ones if the values for obtained for the Cs parameter are greater 0.07. However, it is well known that the reliability of Cs depends on the system modal interaction. According to Figures 3, 4 and 5, it seems that the subsystems are strongly coupled. Moreover, the values for Cs were less than 0.07.

4. CONCLUSIONS

Although the results are encouraging, the lack of more experimental data precludes any definite conclusion on the validity of the Cs values obtained herein. James and Fahy (2000) concluded that the main disadvantage of the Cs is that it is sensitivity to modal proximity. It is also seen that Cs is sensitive to the physical strength of coupling. Thus, a new parameter M_p, was proposed. It is an indicator of modal interaction. Further investigations could be done on the basis of considering this indicator on the analysis. Moreover, the Cs parameter might be calculated to a greater number of straps and a wider frequency range in the next stage of this research. For Cs be considered a reliable indicator of strength of coupling, it is recommended that one should able to distinguish between resonant and non-resonant coupling.

5. REFERENCES

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