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# Study on the Coupling Loss Factor of Two Plates Coupled at Any Angle Based on Wave Method

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**The coupling loss factor (CLF) is an essential parameter in the rapid assessment of high-frequency structural vibration and sound. This paper utilizes the wave motion theorem to formulate the CLF between two flat plates connected at any angle under harmonic wave incidence. The derived CLF formulation is rigorously validated through literature comparison and commercial software simulations. Numerical results reveal that the CLF exhibits pronounced dependence on the incident wave characteristics while demonstrating significant correlations with excitation frequency, coupling configuration, material properties, and geometric parameters of the structural system. This research significantly enhances comprehension of structural energy attenuation.**

## INTRODUCTION

In the analysis of acoustic problems, finite element method/boundary element methods are commonly employed to calculate low-frequency sound and vibration due to the fact that the element size must be significantly smaller than the wavelength of the elastic wave or the acoustic waves. In the high-frequency range, the advent of statistical energy analysis (SEA) has effectively addressed dynamic issues in complex structures and acoustic systems. SEA's notable efficiency and relatively accurate predictive capabilities have led to its widespread adoption not only in sectors like aviation and automotive engineering (Cherif, et al., 2021) but also in the maritime industry for investigating ship noise (Zhang, et al., 2022).

Critical parameters like coupling loss factors (CLF), internal loss factors, and modal density significantly impact the accuracy of the SEA. Moreover, the CLF quantifies the energy loss and influences the energy transfer between the subsystems. CLFs are typically determined using methodologies based on wave motion. Scholars globally have extensively derived the CLF through theoretical frameworks.

It was noted (Langley, 1990, 1994; Langley and Shorter, 2003) that the authors derived the expression of the CLF between coupled structures using the wave-based method. Clarkson (1991) derived the expression of the CLF for beam-beam and plate-plate connections using the modal method. Manning (1994) represented the input power and energy variables of SEA using the admittance of the structure and derived the formula for the CLF, simplifying the expression by averaging the input power and energy. Simmons (1991) proposed a method to solve the coupling loss factor between structures using the finite element method. Sheng et al. (1997, 1999) derived the relationship between nonconservative CLFs and the ratio of structural vibration energy based on the form of energy balance equation for the classic, conservative statistical energy analysis and subsequently studied the method of calculating the CLF of nonconservative coupling systems using the admittance of subsystems. Wang and Zhao (2001) studied the wave characteristics of periodic stiffened damping plates based on the wave method and calculated the CLF of the vertical coupling between flat plates and periodic stiffened damping plates. Chen et al. (2010), based on Mace's derived theory of coupling loss factors for straight connections, derived theoretical formulas for coupling loss factors of folded, curved, and arbitrarily curved connections. Lin et al. (2015) used the finite element method and the power input method to solve the CLF of the steel-aluminum connection in T-shaped connection structures with transition joints. Patil and Manik (2020) studied the vibration transmission through two uniformly isotropic plates connected at right angles using the wave propagation method and experimentally verified the CLF predicted by the wave method using welding, rivets, and bolted joints.

The majority of studies mentioned above concentrated on using the single plate theory to determine the CLF for straight, "L"-shaped, T-shaped, and cross-shaped connections or through experimental testing. However, these studies focus solely on energy transmission coefficients, neglecting CLF variation patterns and exploring only limited coupling angles. Due to the irregularities in many practical shell structures, theoretical formulas for the CLF cannot always be provided for their calculations. Experiment testing requires significant financial and material resources. Therefore, in engineering practice, these complex structures are often treated as connections between finite plates for performance forecasting purposes. Hence, research on the CLF for flat plates connected at arbitrary angles is momentous and will be thoroughly illustrated in this article by varying the junction angles; the geometrical and material parameters; and the coupling of different types of waves.

## DERIVATION OF THE CLF BETWEEN TWO PLATES COUPLED AT ARBITRARY ANGLES BASED ON THE WAVE MOTION METHOD

### Establishing Equations of Motion

The coupled structure of the two plates is shown in Fig. 1. In SEA calculations, this structure is divided into two subsystems (Plate 1 and Plate 2).

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