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HDMR BASED RESPONSE SURFACES FOR PROBABILISTIC BRIDGE VEHICLE INTERACTION STUDIES

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Dynamic effects induced by moving traffic are traditionally accounted for in bridge design by the use of dynamic amplification factors (DAF). A realistic estimation of DAF involves consideration of various uncertainties associated with the vehicle bridge interaction (VBI) problem. These uncertainties include randomness associated road surface roughness, speed and arrival of vehicles, randomness associated with vehicle parameters such as axle loads, axle spacing, suspension characteristics etc. Methodologies for evaluation of DAF in a probabilistic framework using Monte Carlo simulation of traffic flow were proposed by O'Brien et.al [1]. Statistical basis for the traffic flow simulation were based on realistic weigh in motion data involving axle load/spacing, travel speed, accurate time stamps of vehicle arrival for headway modelling etc. Though the methodology is robust, it is computationally intensive as the VBI analysis needs to be performed for many years of simulated traffic. An alternative would be to perform dynamic simulations of selected critical static loading scenarios alone. This too will be cumbersome given the large number of uncertain parameters associated with the bridge vehicle interaction problem.
Response surface methods combined with importance sampling techniques have traditionally been employed in uncertainty analysis to reduce the computational efforts. Recently, improved response surface models based on High Dimensional Model Representation (HDMR) has been proposed [2] and has successfully been applied in simulation based reliability analysis [3]. This paper explores the efficacy of HDMR based response surfaces for use in probabilistic assessment of dynamic amplification factors (DAF) for highway bridges carrying bidirectional traffic. Dynamic response of a bridge resulting from a two critical vehicle meeting scenario, which mostly governs the design of short to medium span bridges is simulated. A computationally efficient bridge vehicle interaction program developed by the authors, which considers a 2D grillage idealization of bridge, planar rigid body MDOF idealization for vehicle and Gaussian random process model for road profiles, was used for the purpose. A schematic of the computational model is shown in Fig.1.The coupled equations of motion with time varying coefficients representing the bridge vehicle system, was solved in time domain using Newmark's time integration scheme. Axle loads, axle spacing, travel speed and suspension characteristics of vehicles in two lanes were treated as random variables. The dependence structure between the axle loads was better captured through use of copula functions as against the traditional use of linear correlation coefficients [4]. A comparison of observed axle loads with simulated ones using a bivariate Archimedean copula for the three axle rigid truck used in simulations is shown in Fig.2. Vehicle types in

two lanes were treated as deterministic. Simulations were performed to extract the peak total response (including dynamic effects) as well as static responses.

Efficiency of Random Sampling High Dimensional Model Representation (RS-HDMR) in capturing the peak static and dynamic bridge responses is explored by comparing the metamodel response predictions with traditional Monte-Carlo simulations. It was observed that RS-HDMR based metamodels are highly efficient in capturing the peak bridge dynamic responses under traffic induced vibrations (Fig.3).

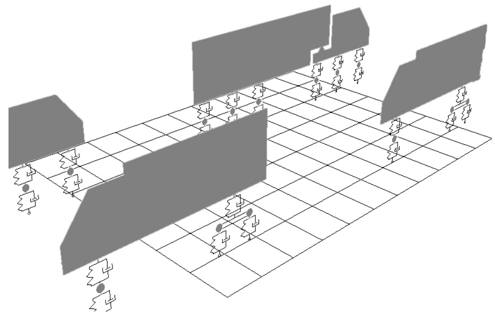

Figure 1: Schematic of developed numerical model

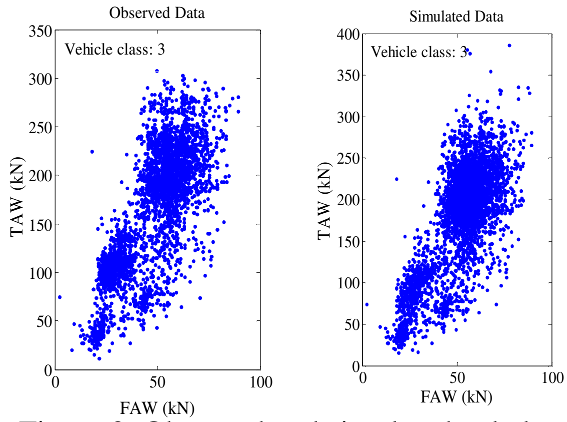

Figure 2. Observed and simulated axle load data for 3 axle rigid truck

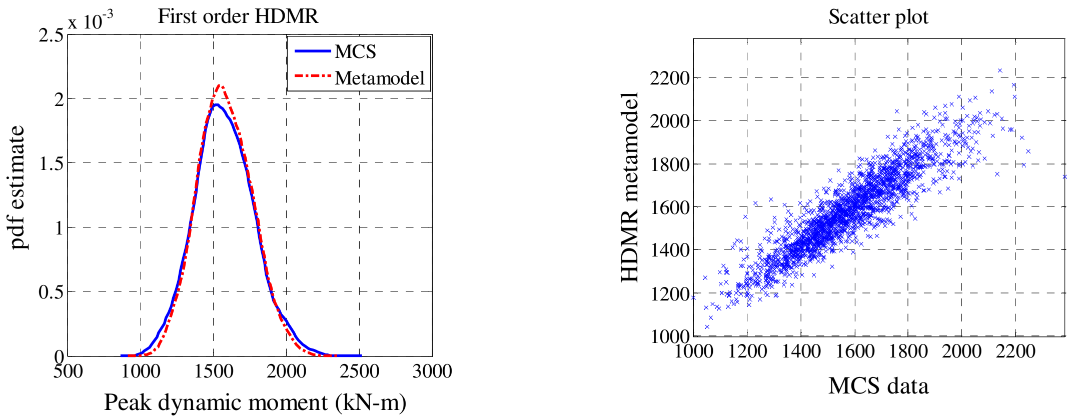

Figure 3. Metamodel efficiency in peak bridge dynamic response predictions

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