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Large Eddy Simulations of Wind Shear from Passing Vehicles Under a Freeway Overpass

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Introduction

Today, wind generated from passing vehicles on roads and freeways is wasted energy. Harnessing this energy adds to California's renewable energy portfolio for various commercial and transportation-related applications. This study investigated the transient wind and load generated from vehicles passing under a freeway overpass in order to check its viability for electric power generation.

Study Methods

The research team performed detailed numerical simulations of a vehicle passing under a freeway overpass near the freeway columns. The study sought to gain a better understanding of the transient wind and pressure distribution characteristics at the bridge columns for potential electric power generation. The vehicle was an Ahmed body, similar to a mid-size SUV, traveling at 23 m/s (51.5 mph) at 0.75 w from the bridge columns where w is the width of the vehicle. The bridge used has six cylindrical columns equally spaced with a diameter of 1.34 m; the spacing between the columns was 2.46 m. The computational domain encompassing the freeway overpass has dimensions of X = 30 m, Y = 11.25 m, and Z = 14.5 m with a grid size of 0.85 cm. Here, X is the direction of the moving vehicle, and Y and Z are vertical and spanwise directions, respectively. An overset grid technique (moving mesh) was used for the moving vehicle. The overset region was 8 m x 3.5 m x 6 m in the X, Y, and Z directions, respectively. The blockage ratio was less than 3%. It took less than a second for the vehicle to pass the bridge columns.

Findings

Results show that the bridge constraints change the baseline vehicle pressure, which affects the transient vehicle's drag coefficient. The transient wind generated at the columns is mostly caused by

the front of the vehicle and ranged from 6 m/s to 10 m/s. The circumferential pressure distributions on the referenced column show that the stagnation point changes with the passing of the vehicle with a maximum differential pressure coefficient of 0.2. The ground effects are seen up to 5 m elevations where the pressure coefficient changes from positive to negative from the passing of the vehicle with a maximum difference of 0.17. Using a high-efficiency vertical axis wind turbine with a 0.35 power coefficient, the potential for power generation at the bridge columns from passing a vehicle is approximately 210 W/m2. With continuous traffic flow, significant electric power could be generated from passing vehicles.

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Policy Recommendations

California is moving toward a 100% clean energy future, and expanded wind energy will be a major component of its future energy portfolio. Innovations in wind energy resources, such as those explored here, will move California closer to achieving its goal. In 2017, the U.S. Department of Transportation provided data showing the total highway vehicle miles traveled was estimated at (a) light-duty vehicles: 3,212,347 miles; (b) short-wheel-base: 2,220,347 miles; and (c) trucks: 181,490 miles. This data indicates the potential of capturing vehicle-generated wind energy for electric power generation.

About the Authors

Dr. Hamid Rahai is a professor in the Departments of Mechanical and Aerospace Engineering & Biomedical Engineering and the Associate Dean for Research and Graduate Studies in the College of Engineering at California State University, Long Beach (CSULB). He has supervised over 70 Master's theses, projects, and PhD dissertations and published more than 90 technical papers. He has received over $11 million in grants and contracts from various federal and state agencies and is owner and co-owner of six awarded and pending patents.

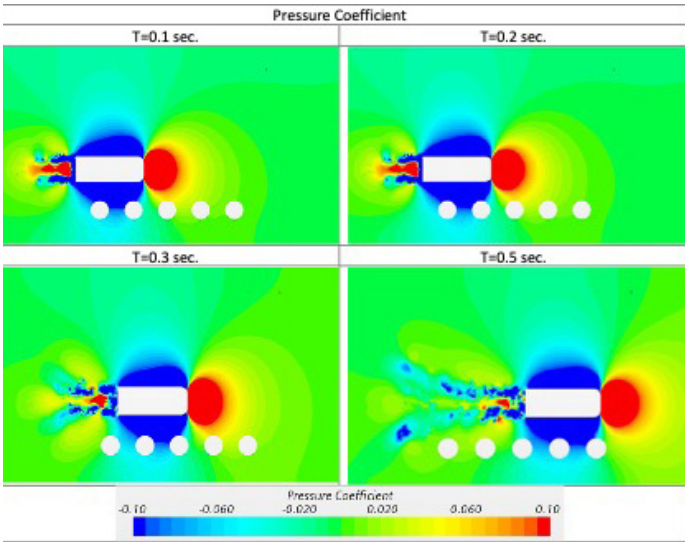

Figure 1. Contours of the Pressure Coefficient Around the Vehicle.

Assma Begum is a Ph.D. student in the joint program in Engineering and Computational Mathematics between California State University, Long Beach's College of Engineering and The Claremont Graduate University (CGU) and a research assistant at the Center for Energy and Environmental Research & Services (CEERS) in the College of Engineering at CSULB.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2145

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