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FE Analysis and Shape Optimization of Wind Tunnel and Spoiler Using CAE Tools

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ABSTRACT

In high speed cars of sedan class, there comes a major problem of lack of grip on road while running at high speeds. This problem comes due to the geometry of the car outer body. This can be understood by considering the fact, that while running, the upper and lower surface relative wind streams has to meet themselves on back side of the car in the same time. A spoiler was fabricated and tested at different wind velocities on Wind Tunnel available at Alfalah University, Faridabad and the tests yielded the respective lift and drag coefficients. It was noticed that as the wind velocity was decreasing lift and drag coefficients were increasing. At the same time the lift to drag ratio was also increasing. Thereafter the three d dimensional simulation of flow over the fabricated spoiler was carried out on the ANSYS 14.0. Workbench. The simulation was done in such a way that it imitated the wind tunnel experiment and also yielded almost same results. Thereafter a comparison was done between the results of wind tunnel experiment and the three dimensional CFD analysis and the percentage error of 3 to 11.11 was recorded. There is find out a small error in Wind Tunnel Experiments and CFD. CFD involves simple geometric construction and changes can be made easily at any stage while actual experimentation requires lots of time and money

INTRODUCTION

The idea of vertical habitation is not new and has been a trend propelled for decades by the growth of cities and the resulting overpopulation. The 16th century Yemeni city of Shibam, which is considered to have the first skyscrapers in the history, is a living example, with mud brick tower buildings of five to eight floors height intended to stave off Bedouin raids. In the late 19th century, new high-rise buildings started to emerge in the North American cities due to social, economic, and technological development. Currently, modern architectures are characterized by their irregular shapes, and tall buildings are becoming taller with complex geometrical forms. As a result, designing and optimizing tall buildings becomes a challenging task, and compounds the problem of collaboration between architects and engineers, where both strive to fulfil different requirements but mutual cost-effective sustainable design outputs. More importantly, tall buildings are sensitive structures to lateral loads such as wind and earthquakes. Nevertheless, while designing for earthquakes, it is essential to lower the structure’s mass and gravity loads in order to control the inertial forces generated by an earthquake.

Applying this will further increase the wind-induced motions and loads on tall buildings to such an extent that it becomes a challenge to meet strength and serviceability design criteria. Thus, wind loads normally dictate the development process of tall buildings and govern the design and optimization of their lateral structural system. Minor modification, with corner configuration being the common type, is a key parameter in manipulating wind responses on tall buildings, where imposing slight modifications on building corners can result in drastic changes in aerodynamic characteristics such as drag, which has a possibility of decreasing up to 60% from the original value according to Tamura. However, when dealing with minor corner modification, the angle of attack (AOA) attributed to wind direction is a key contributor to the effectiveness of the imposed modifications, as demonstrated by a rectangular building shape case study by Miyashita, where no significant impact was recorded for wind blow angles less than 5 degrees. Corner rounding, chamfering, and recession are amongst popular kinds of tall building aerodynamic corner configurations that have been investigated by multiple studies and proved to be effective in mitigating both along-wind and across-wind responses. Elshae established that these types of modifications contribute to the lessening of both wind drag and lift forces on tall buildings. Nonetheless, found that chamfered corners are more potent in reducing drag forces and recessed corners show similar effectiveness in reducing lift forces, where Mandal et al., on the other hand, concluded that rounded corners outperform chamfered in both. Other corner modifications including slotting, fins, and corner-cut are also examined in other studies, and showed similar strong correlations to wind responses on tall buildings. However, Kwok and Baily established that slotted corners effectively mitigate both along-wind and across-wind responses, while fins only help to reduce across-wind response.

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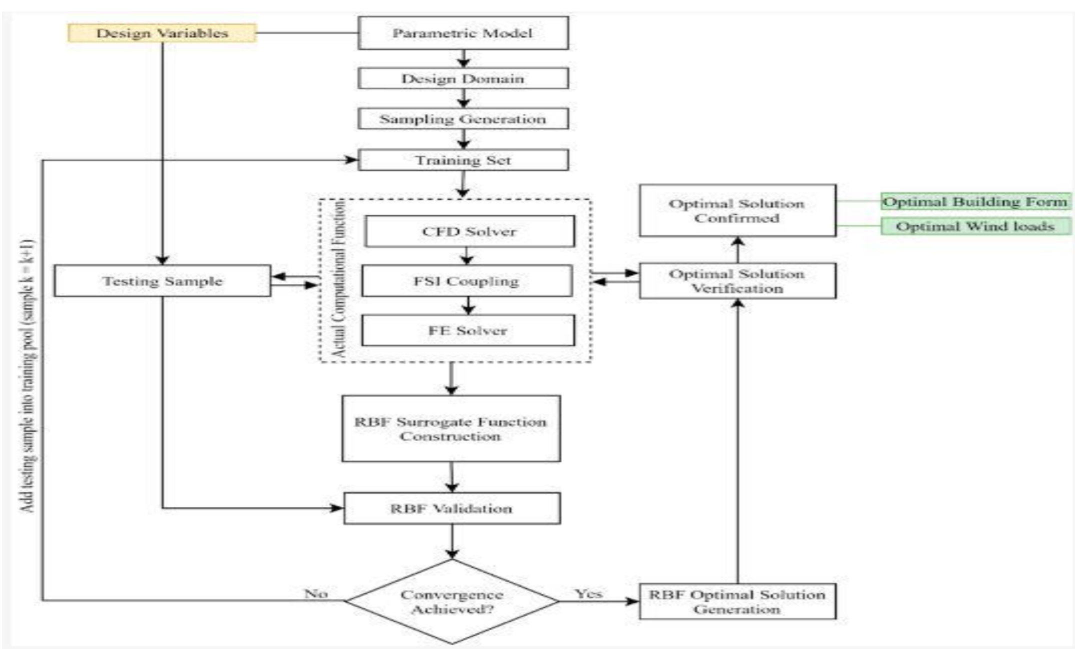
LITERATURE REVIEW

Spoilers are aerodynamic device used in automobiles and faster moving cars to remove turbulence across body of car. It is attached to an automobile. One of the problems for vehicles is to control wake. Suggested method is to change rear body shape and change of shape of spoiler and result of experiments is a great reduction in value of CD and CL (Fukuda, et al. 1995). (Sunanda and Nayak 2013) This study defines that intended function of this device is to “spoil” unfavorable air movement across body of vehicle of some kind in motion. The main function of a spoiler is diffusing airflow passing over and around a moving vehicle as it passes over vehicle. This diffusion is accomplished by increasing amounts of turbulence flowing over shape, “spoiling” the laminar flow and providing a cushion for the laminar boundary layer often spoilers are added solely for appearance with no thought towards practical purpose. Yet again fuel consumption is studied and tried to be reduced by changing conventional material to advanced material. These reforms must be taken care to meet high future demand specifications. In this context suggested material for spoilers is unreinforced thermoplastic (Jambor and Beyer 1997). The most common material in this class is Acrylonitrile Butadiene Styrene (ABS) plastic. For better strength and stress absorption capacity fabrication to be done using sandwich construction in which ±45o orientation of fibers with foam gives better result than ±45o orientation of fibers without foam (Chodagudi and Rao 2012). Comparison of various aspects (likes shape, material) in designing Human Powered Vehicles on various road conditions is studied and found that magnitude of drag depends on physical appearance such that body shape, accessories attached ,extrusions etc. (Alam, et al. 2013) . For smooth flow around spoiler six basic shapes of rear spoiler have been studied and numerical simulation is performed for analysis of stability and noise produced. This analysis suggest that among six shapes case 4, which is an aerofoil shape, has made flow smooth with lower noise level and proposed for spoiler shape (Figure 2.3: Configuration of spoiler (Tsai, et.al. 2009)). The fact it smoothens flow is that it reduces turbulence at tail. Shape optimization is defined as a set of geometrical modeling, structural analysis and optimization. In primary step of making design model, geometrical representation of boundary shapes and design variable are defined. The design optimization problem thus can be written as : Minimize $f(x)$ Subject to $g1(x) \leq 0$ $g2(x) \leq 0$ where x is vector of design variable, $f(x)$ is objective functions, $g1(x) \leq 0$ and $g2(x) \leq 0$ are constraints. Further analysis model is created separately by help of design model. Choice of analysis technique depends upon converting design model into analysis model, capability and accuracy of analysis technique. In next steps optimization algorithm is used to optimize component

METHODOLOGY

Aerodynamic optimization is achieved by employing the surrogate RBF optimization algorithm. Different core processes are involved within every single round of this optimization cycle, including computational fluid dynamics (CFD), fluid–structure interaction (FSI), and finite element analysis (FEA). The aerodynamic optimization process is then developed using the surrogate model technique with a radial basis function met model and includes all previous solvers and coupling within an optimization algorithm (Figure 3.1). The steps involved are illustrated and can be summarized as follows:



NUMERICAL IMPLEMENTATION

A Case Study: An existing irregular tall building project was chosen to implement the proposed optimization method and prove its feasibility and effectiveness. Cayan Tower in Dubai in **Figure 8**, the tallest twisting tower in the world, presents a good example of the current trend of complexity in tall building design. The tower is 306 m in height, with a spiral twisting shape of 90 degrees along its height, inspired by human DNA and designed by the SOM architectural group [**40**]. Although the twisting form is an effective major modification in reducing vortex-shedding dynamic responses of tall buildings in comparison to regular forms, the challenge remains by introducing minor aerodynamic modifications that preserve the design intent of the unique architectural and structural functions of this building to further optimize wind-induced loads with a less expensive and practical computational method.

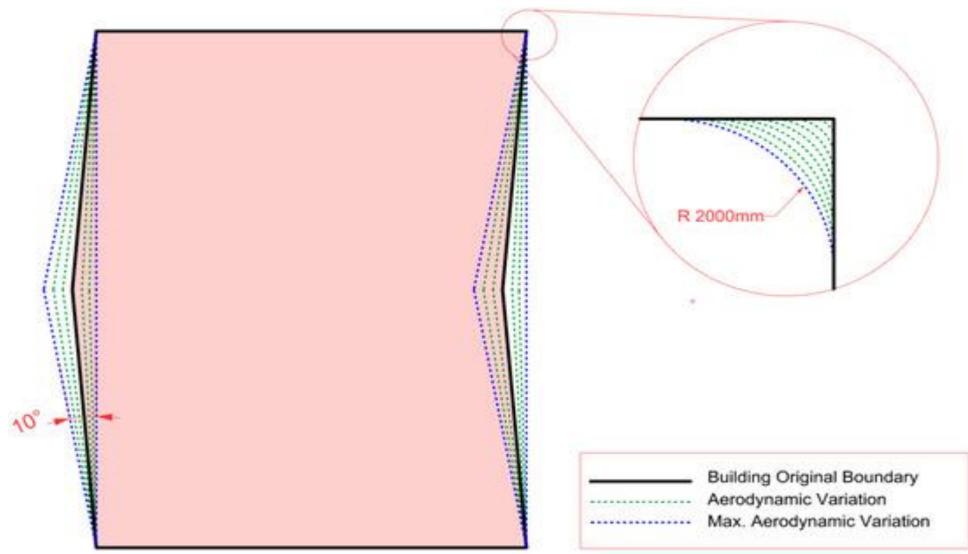


Figure 3.2 Aerodynamic Modification Parameters

FE Analysis

In order to evaluate the structural response to wind action, the finite element analysis was carried out in ETABS and python script was developed to interface with ETABS API and bridge FSI loads with FE analysis in an automotive process.

Structural elements, including lateral resisting system, were all assumed based on the original design of the building and remain constant thorough the height of the structure. A rigid diaphragm was considered to ensure full translation of forces and displacements to the structural lateral system without deforming the contribution from slab stiffness. Forces were applied for each respective story to the center of the diaphragm that represents the center of mass in a given story, so that, in addition to the imposed torsional moment, eccentricity between the center of rigidity and center of mass is taken into account by FE analysis for torsional deformation. Represents the maximum top structural deflections generated for each sampling point, represents the maximum inter-story drifts summarizes the analysis of the ten sampling points according to their respective design variables.

CONCLUSIONS

Here is a small error in Wind Tunnel Experiments and CFD.CFD involves simple geometric construction and changes can be made easily at any stage while actual experimentation requires lots of time and money. That is why CFD analysis is much cheaper than experiments. However the boundary condition data required can only come from experimental techniques. There is still a considerably strong need for wind tunnel experiments to validate CFD data in turbulent flows.

The aerodynamic properties of a spoilers only depend on its cross sectional profile and its plan form. Although only one wind direction was considered in this study, the results showed an effective minimization of structural responses on both along-wind and across-wind directions. The translated percentage of reduction in top structural deflection for both along-wind and across-wind are 12.95% and 14.53%, respectively.

The translated percentage of reduction in inter-story drift for both along-wind and across-wind are 12.89% and 13.54%, respectively.

The translated percentage of reduction in imposed wind loads for both along-wind and across-wind are 13.83% and 23.12%, respectively.

The development of the surrogate model function showed to be effective in estimating highly non-linear functions in the case of large architectural problems.

The efficiency of aerodynamic optimization together with the capability of computational tools are expected to encourage both architects and engineers to employ them while seeking better decisions at preliminary design stages.

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