World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:16, No:07, 2022

Development of a Turbulent Boundary Layer Wall-pressure Fluctuations Power Spectrum Model Using a Stepwise Regression Algorithm

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Abstract : Wall-pressure fluctuations induced by the turbulent boundary layer (TBL) developed over aircraft are a significant source of aircraft cabin noise. Since the power spectral density (PSD) of these pressure fluctuations is directly correlated with the amount of sound radiated into the cabin, the development of accurate empirical models that predict the PSD has been an important ongoing research topic. The sound emitted can be represented from the pressure fluctuations term in the Reynoldsaveraged Navier-Stokes equations (RANS). Therefore, early TBL empirical models (including those from Lowson, Robertson, Chase, and Howe) were primarily derived by simplifying and solving the RANS for pressure fluctuation and adding appropriate scales. Most subsequent models (including Goody, Efimtsov, Laganelli, Smol'yakov, and Rackl and Weston models) were derived by making modifications to these early models or by physical principles. Overall, these models have had varying levels of accuracy, but, in general, they are most accurate under the specific Reynolds and Mach numbers they were developed for, while being less accurate under other flow conditions. Despite this, recent research into the possibility of using alternative methods for deriving the models has been rather limited. More recent studies have demonstrated that an artificial neural network model was more accurate than traditional models and could be applied more generally, but the accuracy of other machine learning techniques has not been explored. In the current study, an original model is derived using a stepwise regression algorithm in the statistical programming language R, and TBL wall-pressure fluctuations PSD data gathered at the Carleton University wind tunnel. The theoretical advantage of a stepwise regression approach is that it will automatically filter out redundant or uncorrelated input variables (through the process of feature selection), and it is computationally faster than machine learning. The main disadvantage is the potential risk of overfitting. The accuracy of the developed model is assessed by comparing it to independently sourced datasets.

Keywords : aircraft noise, machine learning, power spectral density models, regression models, turbulent boundary layer wall-pressure fluctuations
Conference Title : ICMAME 2022 : International Conference on Mechanical, Aeronautical and Manufacturing Engineering
Conference Location : Ottawa, Canada
Conference Dates : July 12-13, 2022