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Uncertainty Factors of a Finite Element Model using the Fuzzy Analysis Method

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ABSTRACT

The recent advancement in manufacturing technology in the automotive and aerospace sectors has led to the invention of advanced structured material, which is lightweight and a complex geometry model that can be manufactured. As it is related to human safety and hazards, the need for uncertainty analysis in a structure before and after a manufacturing process is a primary concern. Thus, this paper analyzes the uncertainty parameters of a meshed finite element model in the geometry, boundary condition, load, and material properties. An uncertainty analysis numerical tool, the fuzzy analysis method, is applied in Excel-VBA as the simulation platform. Each uncertainty parameter is in a range of numbers, with a maximum and minimum value as the limit. The α-cuts determine the fuzzy analysis output on the membership function. The deterministic value of the variable is implemented for comparison purposes. The simulation result for the von-Mises stress analysis has significantly impacted the uncertainty analysis as its curve has surpassed the yield strength limit of the material. The simulation output for the displacement has a more considerable uncertainty dispersion when compared to the other results. This study helps to find a better security margin of a structure for its sustainability in the future.

Keywords: α-cut; finite element method; fuzzy analysis; structural integrity; uncertainty

INTRODUCTION

The latest technological advancement in manufacturing methods has been implemented, especially in the automotive and aeronautic sectors. These new approaches, for example, the rapid prototyping method, are gaining popularity among large manufacturing companies as it helps to produce lightweight end products and can manufacture complex geometry components (Seharing et al. 2020). Giant aeronautic producers such as Boeing, Airbus, and many other automotive companies are establishing this method to produce their high-end products (Jin et al. 2022) as it helps to increase production rate and decrease manufacturing time and cost (Vasilescu et al. 2020).

Despite these technological advancements, structural longevity and sustainability play a vital part, especially when it involves the safety of the users. This is crucial for large structures such as buildings and bridges as they are surrounded by uncertain environments and conditions. These uncertainties are due to the scarcity of information during the manufacturing and modeling phase (Stritih et al. 2019), the law of nature, and human heuristics (Li et al. 2018). Thus, errors are generated when dealing with material attributes, boundaries, and initial states in experimental and engineering scenarios (Hariri-Ardebili et Sudret, 2021).

To overcome these uncertainties, researchers have come out with numerical and mathematical methods such as Neuro-Fuzzy, Artificial Neural Network (ANN), and Fuzzy analysis methods. Each method applies a range of random numbers as the uncertainty parameters. These random numbers of minimum and maximum values are easily obtained compared to specific deterministic values