International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 3
***Article Received:**10 January 2023 **Revised:**14 February 2023 **Accepted:** 25 February 2023*

Enhancement of Grid and Face Element Amendment in Aeroelasticity Analysis by Advanced Self-Adaptive Computing Method

R. Kennady[1], Shiva[2]

[1]Department of Artificial Intelligence and Data Science, Rajalakshmi Institute of Technology, Chennai, Tamilnadu

[2]Department of Computer Science and Engineering, Rajalakshmi Institute of Technology, Chennai, Tamilnadu

[1]kennady.r@ritchennai.edu.in, [2]shiva.s@ritchennai.edu.in

Abstract

This research presents a novel approach for enhancing the accuracy and efficiency of aeroelasticity analysis through the combination of grid optimization and face element amendment techniques. The study focuses on improving the precision of a low order panel method by performing piecewise linear amendment based on Computational Fluid Dynamics (CFD) aerodynamic loads data under varying angles of attack. Additionally, the distribution of face element calculating grid is optimized using visual evoked potential estimation. The proposed method addresses the limitations of traditional panel methods that heavily rely on grid distribution and offers a more robust and accurate solution. The optimized grid not only maintains the computational efficiency of the panel method but also ensures closer approximation of wing stresses to CFD data, thus enhancing the precision and efficiency of aeroelasticity optimized iterative design processes. The results obtained from this research demonstrate effective compensation for the shortcomings of the panel method and a significant improvement in the computational efficiency of aerodynamic loading in the presence of changing structural stiff parameters.

Keywords-Aeroelasticity, Panel method, Grid optimization, Face element amendment, Computational Fluid Dynamics (CFD), Angle of attack, Precision improvement, Efficiency enhancement.

Introduction

Aeroelasticity analysis plays a crucial role in the design and optimization of aircraft wings, ensuring their structural integrity and performance under various aerodynamic loads. Traditional methods for aeroelasticity analysis often employ panel methods, which provide efficient solutions by discretizing the wing surface into a network of panels. However, these methods suffer from limitations regarding the accuracy of the results, particularly when dealing with complex flow conditions and varying angles of attack. To address these limitations, this research proposes an advanced self-adaptive computing method that combines grid optimization and face element amendment techniques. The objective is to improve the precision and efficiency of aeroelasticity analysis by enhancing the panel method's accuracy in capturing the aerodynamic loads on the wing surface. The first aspect of the proposed method involves piecewise linear amendment to a low-order panel method, utilizing aerodynamic loads data obtained from Computational Fluid Dynamics (CFD) simulations under multigroup different angles of attack. By incorporating CFD data, the panel method can be corrected to account for the nonlinear effects of varying angles of attack. This amendment process aims to improve the accuracy of the panel method by refining the estimation of aerodynamic loads. Additionally, the distribution of the face element calculating grid is optimized using visual evoked potential estimation. This optimization technique ensures that the grid is suitably structured to capture the aerodynamic flow characteristics accurately. By improving the grid distribution, the precision of the panel method corrections can be enhanced, reducing the dependence on grid quality and resulting in more reliable aeroelasticity predictions. The proposed method offers several advantages over traditional panel methods. It not only maintains the computational efficiency of the panel method, which is known for its relatively fast computations compared to full CFD simulations, but also ensures that the calculated wing stresses closely approximate the CFD data. This combination of efficiency and accuracy is of utmost importance in aeroelasticity analysis, where reliable predictions of structural behavior are required to inform design decisions. Furthermore, the improved precision and efficiency achieved through the proposed method can significantly enhance the aeroelasticity-optimized iterative design process. By accurately predicting aerodynamic loading and its interaction with structural stiffness parameters, designers can optimize the wing's design to achieve desired performance criteria, such as reducing drag, enhancing stability, and minimizing structural deformation. The figure (Fig.1) shows the formal approach to model complex adaptive computing systems.[5]

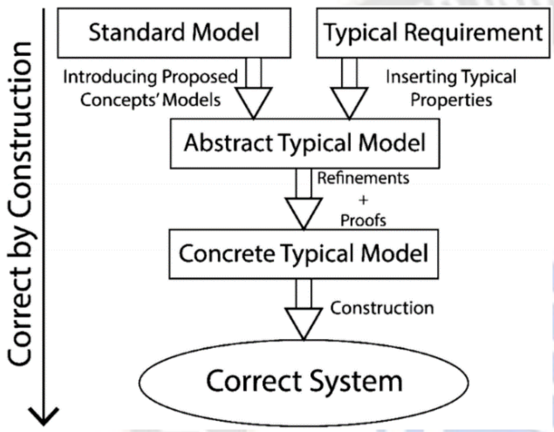

Fig. 1: Complex Adaptive Computing Systems

The outcomes of this research are expected to extend the precision of aerodynamic loading data and CFD computational solutions to nonlinear sections with a variation in angle of attack within a 2% error margin. This enhancement in precision will substantially improve the computational efficiency of aerodynamic loading analysis during structural stiff parameter change procedures. In summary, this research aims to develop an advanced self-adaptive computing method that combines grid optimization and face element amendment to enhance the precision and efficiency of aeroelasticity analysis. By addressing the limitations of traditional panel methods and leveraging CFD data, the proposed method offers a more accurate representation of aerodynamic loads and improved computational efficiency, thus facilitating more effective design and optimization processes in the field of aeroelasticity.

Related Work

In the numerical optimization design of airframe structures considering aeroelastic effects, accurate computations of aerodynamic loading and structural response play a vital role. The aeroelastic effect, which involves the coupled numerical algorithm for deformation and aerodynamic computations, requires high accuracy and efficiency, making it a key technology in modern aircraft analysis.[1] Two frequently used methods for aerodynamic loading calculations in aeroelastic analysis are Computational Fluid Dynamics (CFD) and panel methods based on the potential flow equation. CFD approaches offer high computational accuracy and good agreement with experimental results, leading to extensive research and applications.[2] However, the computational intensity and time required for CFD simulations limit their efficiency, making them primarily suitable for aircraft aerodynamic arrangement and characteristics research. Although concurrent techniques and order-reducing methods can reduce the computational time of CFD, they still cannot meet the efficiency requirements for aeroelasticity iteration optimization design. Additionally, CFD results often do not provide efficient design sensitivity data related to structural variations. [3] In the conceptual phase of modern aircraft design, panel methods are still widely used due to their computational efficiency.

Panel methods have the advantage of adaptability to geometric shapes, requiring fewer grid elements, and being independent of structural parameters in the aerodynamic influence matrix. Hence, panel methods are considered ideal engineering tools for analyzing aerodynamic loading and elastic coupling design. However, panel methods suffer from limitations due to their linear theoretical foundation, as they cannot account for factors such as thickness, viscosity, and shock waves. [4] These limitations restrict their applicability to certain scenarios. In recent years, several modification methods have been proposed to address the deficiencies of panel methods and improve computational accuracy. These advancements aim to overcome the limitations by considering the impact of additional factors such as thickness, viscosity, and shock waves, resulting in noticeable improvements in computational accuracy.

Research Objective

The main objective of this research is to develop an advanced self-adaptive computing method for grid optimization and face element amendment in aeroelasticity analysis. The specific goals include:

- Performing piecewise linear amendment to a low order panel method using CFD aerodynamic loads data under different angles of attack.
- Optimizing the distribution of face element calculating grid using visual evoked potential estimation.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 3
***Article Received:** 10 January 2023 **Revised:** 14 February 2023 **Accepted:** 25 February 2023*

- Improving the precision of panel method corrections by adaptively optimizing the bin grid.
- Addressing the limitations of traditional panel methods by reducing their dependence on grid distribution.
- Maintaining the computational efficiency of the panel method while ensuring closer approximation of wing stresses to CFD data.
- Enhancing the precision and efficiency of aeroelasticity optimized iterative design processes.
- Extending the aerodynamic loading data precision and computational solution accuracy within 2% error for nonlinear sections with varying angles of attack.
- Increasing the computational efficiency of aerodynamic loading in the presence of changing structural stiff parameters.

Grid and Face Element Amendment in Aeroelasticity Analysis

This research focuses on a novel approach for face element amendment and an advanced self-adaptive computing method for grid optimization in aeroelasticity analysis. The proposed method involves several steps to enhance the accuracy and efficiency of the analysis process. In the first step, the original rigid body aerodynamic loading data is calculated for different angles of attack on the lower wing component. Computational Fluid Dynamics (CFD) simulations are performed using a non-structural grid lattice, with the airfoil member used as a rigid solid. The pressure distribution data on the wing's surface is extracted from the CFD simulation results to determine the original aerodynamic loading data. Next, the deformation rigid body aerodynamic loading data is calculated. An angle of attack is selected in the non-linear section of the airfoil lift curve, and the aerodynamic loading calculated in the previous step is applied to the wing. The wing's tip torsion angle is determined using NASTRAN software, and the wing's geometry is adjusted in CAD software to ensure a linear change in torsion angle from the wing root to the tip. The modified wing geometry is then used to create a new CFD grid, and conventional CFD simulations are performed to extract the pressure distribution on each aerofoil grid node, obtaining the deformation rigid body aerodynamic loading data.

In the subsequent steps, grid parameter initialization and grid graduation are performed to optimize the mesh distribution. The wing's surface is opened up and arranged in a mesh point using cubic curve interpolation and tangential cubic curve arrangement. The bin grid graduation is carried out on the airfoil chord plane using a geometric algorithm, considering the given parameters and mesh point quantities. The panel method is then utilized to calculate the aerodynamic force matrix. The grid distribution obtained in the previous step is input into ZAERO software to create the aerodynamic influence matrix under the reference flight condition. This matrix represents the aerodynamic forces acting on the wing and is consistent with the flight conditions considered in the CFD simulations. Finally, the aerodynamic loading distribution is modified using a segmentation gradient correction panel method to obtain a revised load distribution. The original rigid body CFD data obtained in the first step is used to correct the aerodynamic influence matrix of the panel method. A piecewise linear face element amendment is applied to improve the accuracy of the panel method's calculations, enhancing the precision of the aerodynamic loading distribution. The below figure (Fig.2) shows the block diagram of the proposed smart grid system.

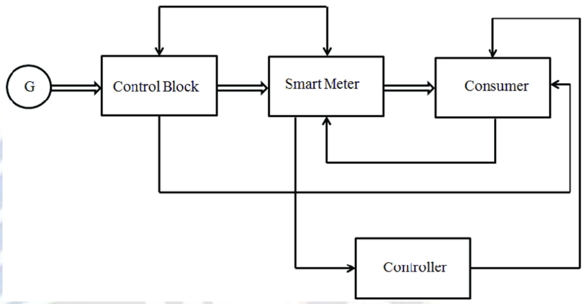

Fig. 2: Diagram of Proposed Smart Grid System

Overall, this research presents a comprehensive method that combines face element amendment and grid optimization to improve the accuracy and efficiency of aeroelasticity analysis. The proposed approach addresses the limitations of traditional panel methods and leverages CFD simulations to refine the aerodynamic loading calculations. By optimizing the grid distribution and applying advanced panel method techniques, the research aims to enhance the accuracy of aeroelasticity predictions in the design and optimization of airframe structures.

Conclusion

In this research, a novel approach combining face element amendment and advanced self-adaptive computing methods for grid optimization in aeroelasticity analysis has been proposed. The objective was to improve the accuracy and efficiency of aeroelasticity predictions in the design and optimization of airframe structures. The research developed a systematic process comprising several steps. The original rigid body aerodynamic loading data was calculated for different angles of attack using CFD simulations and a non-structural grid lattice. The deformation rigid body aerodynamic loading data was then obtained by applying the calculated loads to the wing and considering the resulting wing deformation.

To optimize the mesh distribution, grid parameter initialization and grid graduation techniques were employed. The cubic curve interpolation and tangential cubic curve arrangement were used to open up the wing surface and arrange mesh points accordingly. Additionally, a geometric algorithm was applied to perform bin grid graduation on the airfoil chord plane. The panel method was utilized to calculate the aerodynamic force matrix, taking into account the modified grid distribution. The aerodynamic influence matrix was created using ZAERO software, considering the reference flight conditions and CFD data obtained in the earlier steps. Furthermore, the aerodynamic loading distribution was modified using a segmentation gradient correction panel method, improving the precision of the panel method calculations.

The piecewise linear face element amendment technique was applied to refine the aerodynamic loading distribution, resulting in enhanced accuracy. Overall, this research presents a comprehensive methodology that addresses the limitations of traditional panel methods and leverages CFD simulations to improve the accuracy of aeroelasticity analysis. By optimizing the grid distribution and incorporating advanced panel method techniques, the proposed approach offers improved precision in predicting aeroelastic behavior during the design and optimization of airframe structures. The outcomes of this research have significant implications for the aerospace industry. The enhanced accuracy and efficiency of aeroelasticity predictions enable designers to make informed decisions regarding structural integrity, performance optimization, and stability.

By combining grid optimization and face element amendment techniques, this research contributes to advancing the state-of-the-art in aeroelasticity analysis and paves the way for more efficient and reliable aircraft design processes. Future research directions could involve further refining the proposed methodology, exploring additional modification methods, and validating the results through experimental testing. Moreover, the application of this approach to other complex aeroelastic problems and different aircraft configurations would expand its scope and applicability in the field of aerospace engineering.

References

1. Oldfield, M. K., Castillo Pardo, A., & Hall, C. A. (2022). Fan Stability Enhancement With Partial Casing Treatments. *Journal of Turbomachinery*, *144*(12), 121010.
2. Machine learning-based CFD simulations: a review, models, open threats, and future tactics D Panchigar, K Kar, S Shukla, RM Mathew - Neural Computing and 2022 – Springer
3. Review on bio-inspired flight systems and bionic aerodynamics HAN Jiakun, HUI Zhe, T Fangbao, C Gang - Chinese Journal of 2021 – Elsevier
4. Development of suitable closed loop system for effective wind power control using different ZSC topologies and different switching techniques PR Choube, VK Aharwal - Journal of Integrated Science and 2022 - pubs.iscience.in
5. Optimization for Control, Observation and Safety G Valencia-Palomo, FR López-Estrada, D Rotondo - 2020 - books.google.com
6. Selection guidelines for wind energy technologies AG Olabi, T Wilberforce, K Elsaid, T Salameh - Energies, 2021 - mdpi.com
7. 14th International Conference on Automatic Control and Soft-Computing CONTROLO'2020: book of abstracts J Gonçalves, M Braz-César, JP Coelho - 2020 - bibliotecadigital.ipb.pt
8. Selection guidelines for wind energy technologies AG Olabi, T Wilberforce, K Elsaid, T Salameh - Energies, 2021 - mdpi.com