OPTIMIZING WING STRUCTURE DESIGN AND CONDUCTING STATISTICAL ANALYSIS FOR PREDICTING FATIGUE LIFE IN TRAINER AIRCRAFT

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ABSTRACT

A CATIA project was used to extensively design the wing structure of a training aircraft as part of this investigation. The strains being applied to the wing structure are then determined by doing a stress analysis on it. With the aid of ANSYS, the finite element approach is used to anticipate the stresses in order to compute the safety factor of the structure. A fatigue fracture may occur in an airplane's structure where the greatest tensile stress is placed. Three components are required for life prediction: local stress history at the stress concentration; a model for the buildup of fatigue damage; and constant amplitude S-N (stress life) data throughout a range of stress ratios. An examination of the wing's structural reaction is planned. This research focuses on the skin, spars, and ribs of the trainer aircraft's wing construction. The wing is composed of two skin-covered spars and fifteen ribs. There is a "I" portion on the front spar and a "C" form on the rear spar. A stress and fatigue evaluation of the whole wing section must be completed in order to determine the stresses that the applied pressure load will place on the spars and ribs.

Potential search phrases include aircraft wing, static analysis, CATIA, fatigue life prediction, and Ansys.

1. INTRODUCTION

A wing is a type of fin that produces lift, while moving through air or some other fluid. As such, wings have streamlined cross-sections that are subject to aerodynamic forces and act as airfoils. A wing's aerodynamic efficiency is expressed as its lift-to-drag ratio. The lift a wing generates at a given speed and angle of attack can be one to two orders of magnitude greater than the total drag on the wing. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at sufficient lift. Lifting structures used in water, include various foils, including hydrofoils. Hydrodynamics is the governing science, rather than aerodynamics. Applications of underwater foils occur in hydroplanes, sailboats and submarines.

1.1 Aircraft wing

The wing might be considered as the most significant part of a flying machine, since a fixed-wing flying machine can't fly without it. Since the wing geometry and its highlights are affecting all other air ship parts, we start the detail configuration process by wing structure. The essential capacity of the wing is to produce adequate lift power or just lift (L). Be that as it may, the wing has two different preparations, specifically drag power or drag (D) and nose-down pitching minute (M). While a wing architect is hoping to amplify the lift, the other two (drag and pitching minute) must be limited. Actually, wing is expected promotion a lifting surface that lift is created because of the weight distinction among lower and upper surfaces. Streamlined features course readings might be concentrated to revive your memory about numerical systems to figure the weight conveyance over the wing and how to decide the stream factors.

2. MODELING AND ANALYSIS

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used. Its use in designing electronic systems is known as electronic design automation, or EDA. In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

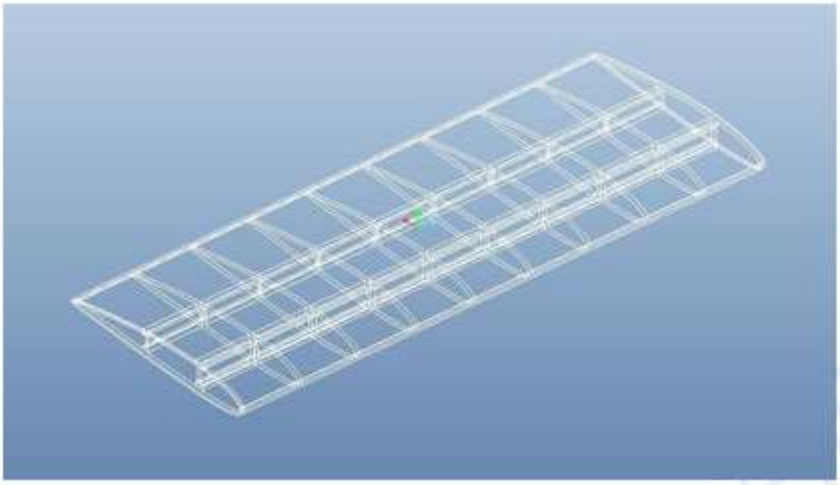

Fig. 1: 3D model of ribs and spars.

CATIA is an acronym for Computer **A**ided **T**hree-dimensional **I**nteractive **A**pplication. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products. CATIA provides the capability to visualize designs in 3D. When it was introduced, this concept was innovative. Since Dassault Systems did not have an expertise in marketing, they had revenue sharing tie-up with IBM which proved extremely fruitful to both the companies to market CATIA. In the early stages, CATIA was extensively used in the design of the Mirage aircrafts; however the potential of the software soon made it a popular choice in the automotive sector as well. As CATIA was accepted by more and more manufacturing companies, Dassault changed the product classification from CAD / CAM software to Project Lifecycle Management. The company also expanded the scope of the software.

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in. Vibrational analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure. Fatigue analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

Material properties

ALUMINUM 6061-T8

Density = 2.7g/cc

Young’s modulus = 69.0GPa

Poisson’s ratio = 0.33

S2 GLASS

Density = 2.46g/cc

Young’s modulus = 86.9GPa

Poisson’s ratio = 0.28

CARBON EPOXY

Density = 1.60g/cc

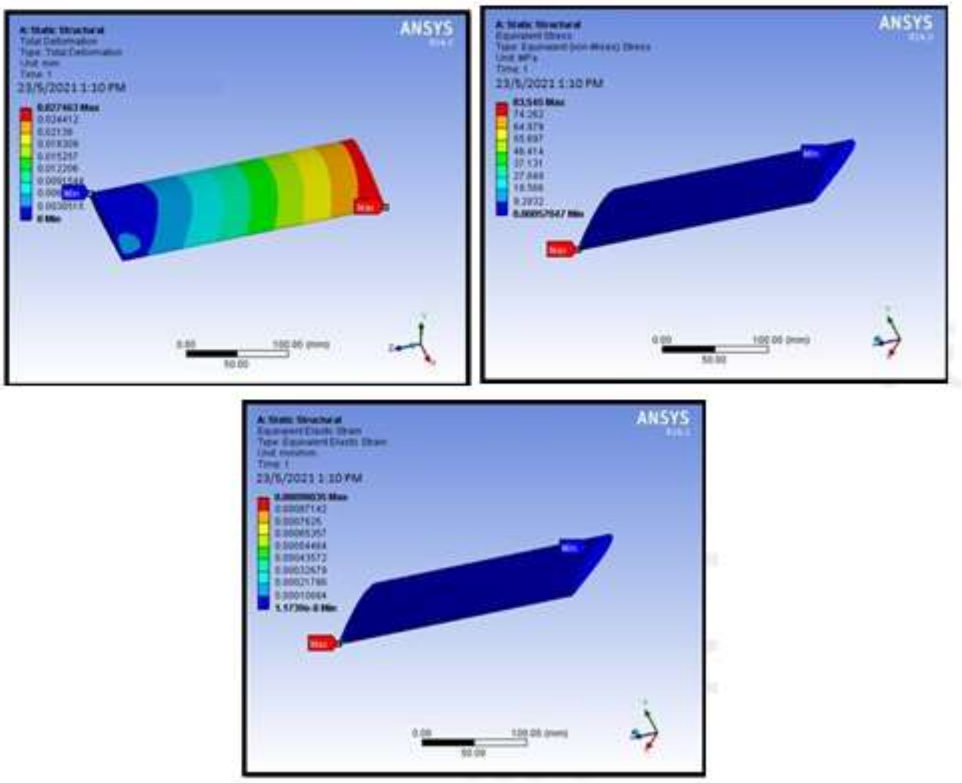

Fig. 2: Deformation (top left). Stress (top right). Strain (bottom).

3. FATIGUE ANALYSIS OF AIRCRAFT WING

Young’s modulus = 70.0GPa

Poisson’s ratio = 0.3

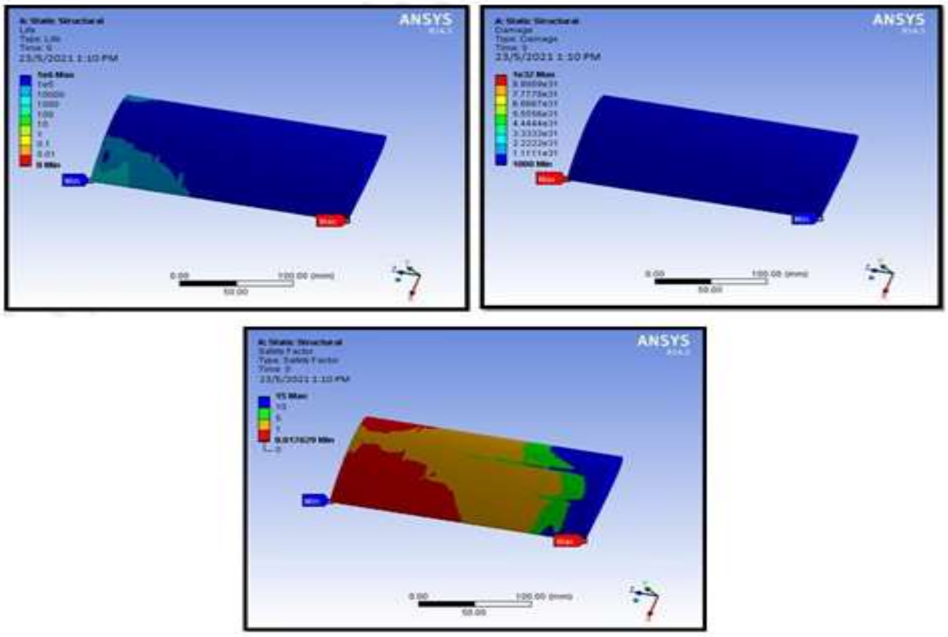

Fig. 3: Life (top left). Damage (top right). Safety factor (bottom).

4. RESULTS

STATIC ANALYSIS

Material	Deformation(mm)	Stress (MPa)	strain
aluminum 6061-T8	0.034562	83.399	0.0012383
s2 glass	0.027463	83.545	0.00098035
carbon fiber	1.9943e-5	48.896	0.00071355

FATIGUE ANALYSIS

Material	life	damage	Safety factor
aluminum 6061-T8	1×e6	1×e32	0.010336
s2 glass	1×e6	1×e32	0.010318
carbon fiber	1×e6	1×e32	0.017629

5. CONCLUSION

The research conducted on wing structure optimization and statistical analysis to forecast fatigue life in trainer aircraft offers significant insights into improving the robustness and security of aircraft parts. Wing structural design and fatigue life prediction are two problems that the study successfully tackles by using statistical methodologies and sophisticated optimization techniques.

Significant increases in structural performance and weight economy have been shown by the optimization process, which makes use of computational tools and design factors. The study's optimization of the wing design led to a reduction in operating expenses and an improvement in aircraft performance by striking a balance between strength and weight.

With the use of simulations and real-world data, statistical analysis of fatigue life has made it possible to forecast the lifespan of the wing structure more precisely. This study offers a strong foundation for comprehending how different loading scenarios and operating pressures affect the wing's performance over time.

The results show that the optimized wing structure provides improved fatigue resistance, increasing the training aircraft's service life and pilot safety. The research emphasizes how crucial it is to combine statistical analysis and optimization methodologies to provide trustworthy and effective design solutions in aeronautical engineering.

- Subsequent research endeavors have to concentrate on enhancing optimization methods, integrating intricate loading circumstances, and verifying the outcomes via empirical data. Improved aviation safety regulations and stronger aircraft constructions will result from more study in this field.

- The study's overall findings emphasize the vital roles that statistical analysis and design optimization play in improving aerospace engineering procedures and guaranteeing the long-term dependability of trainer aircraft wing structures.

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