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Review Article

DESIGN & ANALYSIS FOR FASTENERS FOR UTILITY OVER ENGINEERING APPLICATIONS

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INTRODUCTION

The joints in aircraft and automotive structures lead to regions of stress concentration. Composite materials are relatively brittle and typically offer limited stress relief through localized yielding compared to metals. This, combined with inadequate failure prediction capabilities, can lead to conservatively designed composite bolted joints which amount to severe structural weight penalties. Bonded joints offer higher structural efficiency, but limit accessibility and can increase manufacturing and maintenance costs. Optimizing composite bolted joints using improved modeling tools thus continues to be a priority for airframe manufacturers. Countersunk fasteners are of particular interest for use in skin-structure joints where aerodynamic efficiency is important. Many of these joints are single-lap in nature.

Single-lap joints result in significant stress concentrations and lower bearing strengths compared to double-lap joints, while countersunk joints clearly involve a highly complex stress distribution in the laminates. Thus countersunk, single-lap joints are of critical importance to the aircraft industry, but are also the most complex type to analyze. To date, there have been few detailed studies on this type of joint.

RELEVANCE

The contemporary demands in different branches of Engineering - Aerospace, Automotive, Naval, etc. - require application of new multi-component materials and structural systems. An appropriately chosen joining technology can offer significant enhancement of structural system performance in terms of effectiveness, reliability, safety and other design criteria. The modern applications of joints (e.g. bonded/riveted, bonded/bolted, etc.) are of great technological interest as they permit to combine and to enhance the individual performance of each kind of joint. This is of great importance for in different branches of engineering such as aerospace, mechanical and civil. The advantages to be explored could be in the form of : Higher static and fatigue strength; Stiffer structure; Two-stage cracking process before the final failure, first in the adhesive layer and then in the rivets; Better corrosion resistance.

PRESENT THEORIES & PRACTICES

Presently, the mechanical properties are ascertained vis-à-vis the application through tests over conventional Testing machines and equipments namely, UTS, Izod Impact, Hardness, etc. There is a scope for reducing the time needed for development and testing further.

FEA tools and techniques are being proposed for addressing the nuances of the given application while optimizing the needs of the overall project.

- **Finite Element Analysis**

  Finite element method is used to analyze structures by computer simulations and therefore it helps to reduce the time required for prototyping and to avoid numerous test series. The modeling and analysis will be done using Finite element Analysis software.

- **Steps for finite element analysis:**

  FEA is mainly divided into three following stages:

  - Preprocessing
    - Creating the model.
    - Defining the element type
    - Defining material properties
    - Meshing
    - Applying loads
    - Applying boundary conditions
  - Solution: Assembly of equations and obtaining solution
  - Post processing: Review of results such as deformation plot, stress plot, etc

PROPOSED WORK

The aim of this work is to compare the various types of assembly techniques and harness the same for fastening the elements together. The standard fitments frequently observed would be benchmarked for analysis and the dissertation work would then focus on typical application/s experienced by the client.

Design applications for a particular type of joining method can be suggested on following basis:

- Material of the elements to be joined
- Packaging and space constraints
- Geometry for the elements
- Boundary conditions for the mating parts
- Type and magnitude of loads acting on the assembly
- Specific requirements to be addressed as a part of corporate / regulatory compliance

The study will focus on modifying few of above stated parameters to suggest improvements in existing method of fastening. First, study will focus on studying existing design and based on observations, design improvements will be suggested. Modified design will be tested using FEM software for deflection, impact force and stress distribution. Results of modified fastener configuration/ assembly of the elements will be compared against existing design. FEM is backbone of today's automotive industry. In recent time FE analysis is widely used to validate the complex designs. Use of FEA not only reduces product development time but also saves lot of cost. Hence, this work proposes FE analysis to validate the design modifications. Overall objectives of this study are as stated below:

- To study existing configuration of assembly and the method of fastening

- Carry out structural analysis for stresses induced by tensile/ torsion/ shear loads
- To identify suitable method of fastening (threaded fasteners/ rivets/ spot welded joints/ adhesives etc)
- To review the proposed modifications
- To evaluate the modified design using FEA
- Testing and experimentation

Typical Steps involved in this project work are mentioned as below:

Following steps will be performed to execute this project. Following table gives details of steps and expected schedule.

Task	Remark
Literature Review Understanding functional requirements of fasteners	
To study existing fastening techniques for various functional requirements and list out advantages and limitations of existing design	
CAD modeling for the existing application	3D model creation using CATIA/ UG/ or any other suitable 3D interface
Analysis using CAE	Design validation using Nastran or any other suitable CAE interface
Design modification for the application	By utilizing the inputs from CAE
Analysis for the modified configuration elements	Design validation using Nastran or any other suitable CAE interface
Testing and Validation	Experimentation over the test setup
Report Writing	Documenting results for proposed solution

Experimentation

The experimental program would consist of the estimation of the mechanical properties of the components involving the threaded fasteners and the mechanical response determination of the same upto final failure. The considered joints are planned for subjecting to uni-axial tension and/or shear.

The test setup would include variants for the sheet/ plate to be joined of the same/ different materials. Appropriate type of the fastener to be selected along with suitable specs (material and size). Tests to be conducted based on the projected real-time conditions to be experienced by the application. Typically, tensile tests/ Shear Tests are expected to be experienced by the application.

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