International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031(Online)
www.ijlret.com‖ Volume 1 Issue 3‖August 2015 ‖ PP 37-42

Three Dimensional Analysis Of Fits And Effect Of Layer Orientation In Laminated Composites Under Press Fits For Static And Dynamic Stability

Prapul Chandra AC[1], Narahari GA [2], Prabhnandhan GS[3]
[1] *Asst Professors, VKIT, Bangalore.*
[2] *Asst Professors, VKIT, Bangalore.*
[3] *Asst Professors, GCE Ramanagarm.*

Abstract: Fits plays important role in structural integrity, load carrying capacity and vibrations. Proper fit increases the life of the joint. In the present work, an analysis has been carried out to find effect of fit on radial stress and contact pressure for Aluminum and composite materials. A three dimensional modeling approach is consider studying contact nature, loading carrying capacity and induced stresses. Also stress distribution is calculated for different layer orientation of composite materials. Finally modal analysis is carried out to find the dynamic stability of the structure. A system with higher natural frequency is considered as more stable compared to lower frequency system. The analysis results shows higher natural for interference fits compared to the clearance and push fits. Similarly composite structure modal analysis results indicate, dynamic stability is a function of layer orientation. This conclusion is very important in usage of composites for dynamic structure. A through analysis is required for improving the dynamic stability of the composites.
Key Words: *Structural integrity, Dynamic stability, fatigue damage. Modal analysis, induced stress*

Introduction

A composite is structural materials which consist of combining two are more constituent. The constituent are combined at a microscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fires, partials or flakes. The matrix phase materials are generally continues. Example of composite system include concert Reinforced with steel, epoxy reinforced with graphite fibers, etc.

Steps Used for the analysis of problem in FEM are:

- **Pre-processing**
  It is the act of preparation of data such as nodal locations, element connectivity co-ordinates imposing boundary condition application of load and providing material.
  Information to element and etc. one can decide in this stage regarding the no. of nodes, elements, types with their order and the pattern of FH mesh.
- **Processing**
  This stage of involves stiffness generation, strain energy calculation and solution of equations resulting in the evolution of nodal variables, induced elemental forces, strains and stresses.
- **Post –processing**
  The geometric deformation and distribution of forces, stresses and strain in the structure. Here the aspect of plotting a displaced plotting nodal data in the form of contour plots, such as isotherms and isobars, and conversion of element oriented data into best fitting nodal values is discussed.
  Preprocessing and post processing are integral parts of finite element analysis. The general purpose mesh generation scheme can model a variety of complex regions. The node numbering gives spars matrices and in many cases should give minimum band width proper block representation. Mesh plotting shows the element layout.

2. Problem Definition and Scope of Present Work:

2.1 Definitions:

Analysis of push fit, interference fit and clearance fit pin joints by using laminated composites and modal analysis of the three different fits is the main objective of the problem.

2.2 Requirements:

In mechanical engineering, there are multiple methods for fastening objects together. A pin joint is a solid cylinder-shaped device, similar to a bolt, which is used to connect objects at the joint area. This type of joint connection allows each object to rotate at the point of joint connection.

Most mechanical devices that require bending or opening typically use a pin joint. These joints can be welded solid or allow movement between the two connected objects. A door hinge is a simple example of a free-moving pin joint. The hinge has a pin that allows the door to connect and open freely in the door jam. In this design, the pin is the only device holding the door hinge to the door jam.

A steel-framed truss bridge is an example of a solid-welded pin joint. These bridges have steel beams of multiple angles that are connected together with solid pins. These pins allow the connection of severe angles within the bridge support systems. The solid pins are typically bolted together at the joint area and welded tight. This adds strength and prevents the joints from collapsing under stress.

- Finite element modeling of laminated composite plate using Ansys.
- Comparative strength study of aluminum and composite members.
- Effect of layer orientation on the structural strength.
- And effect of dynamic strength of composites and aluminum can be predicted by using modal analysis.

2.3 Geometrical Models of Plate with Different Fit Joints:

(a) Push fit (b) Interference fit: (c) Clearance fit

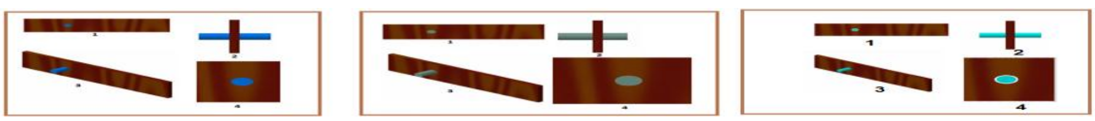


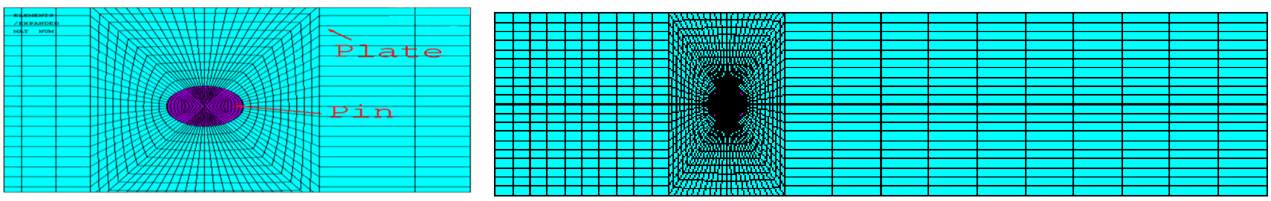
Fig 2.3: Geometrical models

The figure 2.3(a): shows geometrical modeling of problem. A push fit (**same** diameter of plate hole and pin used), An interference fit (diameter of plate hole is **less than** the pin used, A clearance fit (diameter of plate hole is **greater than** the pin used) in pin joint. The configuration is shown above.

2.4 Methodology:

- Modeling for the dimensions using ANSYS software using mixed approach.
- 2 Dimensional Meshing and extruding to form three dimensional mesh of the components of assembly.
- Analysis of the problem for aluminum properties.
  Analysis of the same problem with composite (glass epoxy resin) properties.
- Contact definition between shaft and the plate.
- Nonlinear analysis of the problem by defining yield point to find failure load.
- Comparison of strength between aluminum and composite members.
- Analysis for push and interference fits.
- Failure predictions for composite materials
- Dynamic strength of aluminium & composite member and comparison.
- Results presentation.

2.5 Meshed Plot:



.

Fig 2.5: Meshed Model of the problem.

The above figure shows pin surface extraction from the geometry using hyper-mesh. The pin joint are solid meshed and pined plate mesh to apply the composite properties.

2.6 Boundary Conditions Plot

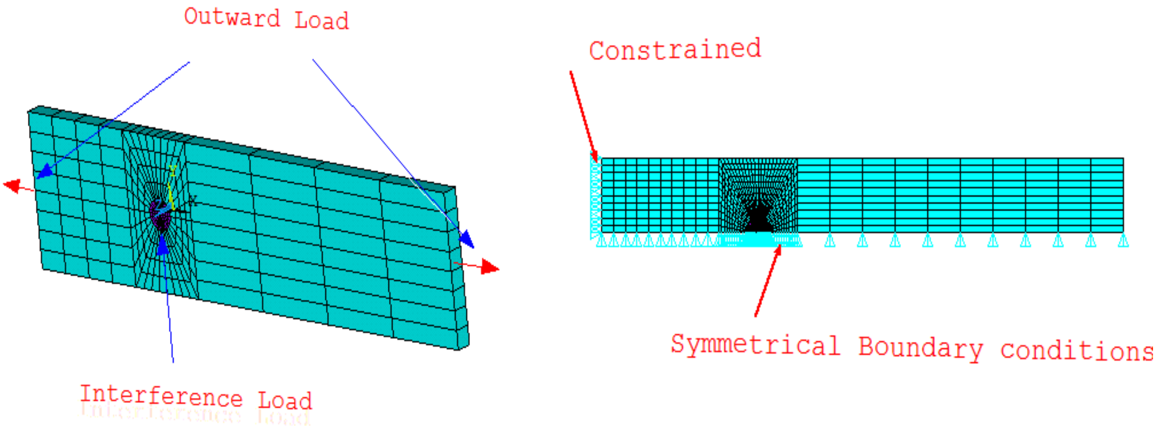


Fig 2.6: Geometrical models boundary conditions

Figure 2.6 (a): shows the boundary condition for outward and interference load in plate with pin joints and symmetrical boundary condition for outward and interference load in half plate with pin joints.

3.Results and Discussions

The composites usage of different pin joints is demonstrated and results are presented. The analysis process is divided as follows.

- Analysis based on aluminum material up to the failure load.
- Composite analysis for the same load and the maximum strength.
- Analysis up to failure of the structure.
- Modal analysis is carried out, and the results are presented for aluminium member and composite member.

3.1 Assumptions:

- ✓ The material is considered are isotropic material.
- ✓ Laminated composite member have different degrees of layer orientation.
- ✓ All FEM approximations are applied for the problem.
- ✓ Mid surface extracted for analysis.

3.2 Different Pin Joints with Zero Loads:
3.2.1 Clearance Fit:

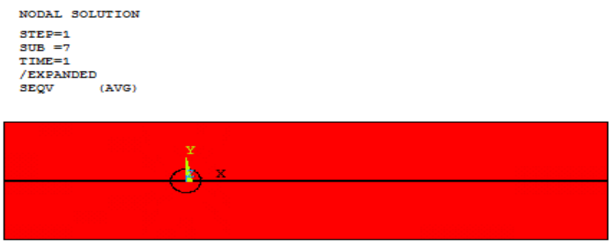


Fig 3.2.1: Clearance fit

The above figure shows Clearance fit with no external load. The maximum structural deformation is around zero which indicates no stress in the member.

3.2.2 Push Fit:

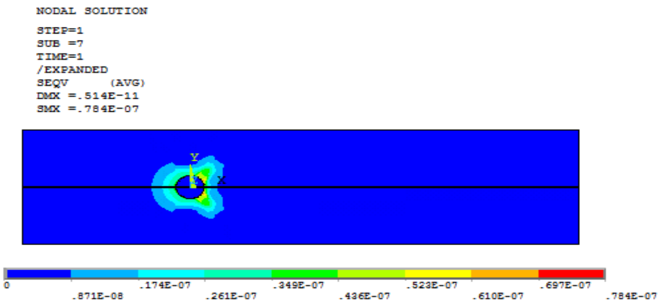


Fig 3.2.2: Push fit

The above figure shows push fit with no external load. The maximum structural deformation is around 0.514E-11mm and the stress developed is 0.78E-07 Mpa

3.2.3 Interference Fit (Interference Value=0.01):

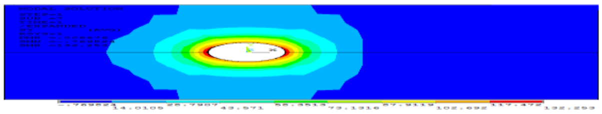


Fig 3.2.3: Interference fit

The above figure shows interference fit with no external load. The maximum structural deformation is around 0.006676mm and the stress developed is 132.253 Mpa.

3.2.4 Stress in pin (0.01 Interference):

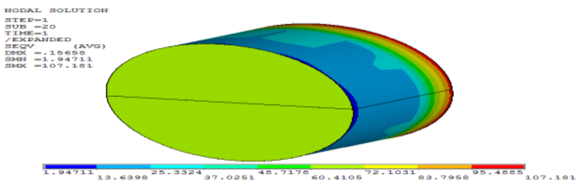


Fig 3.2.4: Stresses in pin - interference pin joint

The above figure shows stresses in pin for interference pin joint. The maximum structural deformation on pin is around 0.15658mm and the stress developed is 107.181Mpa

3.2.5 Stress in plate (0.01 Interference):

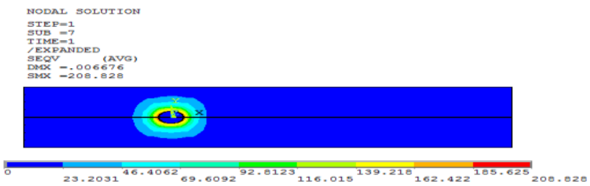


Figure 3.2.5: Stresses in plate - Interference pin joint.

The above figure shows stresses in plate for Interference pin joint. The maximum structural deformation in plate is around 0.006676 mm and the stress developed is 208.828 Mpa.

3.2.6 Contact pressure

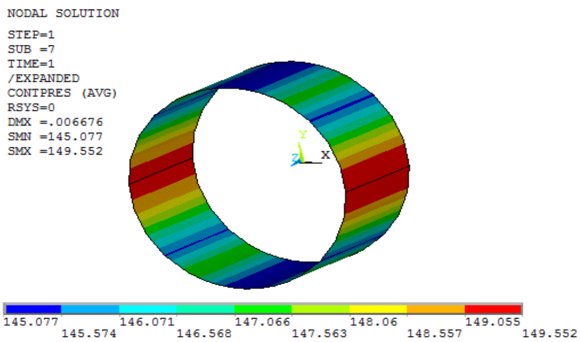


Figure 3.2.6: Circumferential contact pressure - interference fit

The above figure shows circumferential contact pressure between pin and plate. The maximum structural deformation is 0.155806mm and the contact pressure is 149.5 N/mm^2.

3.2 Tabular Representation – zero Load

Type of Fit	Contact Pressure(Mpa)	Radial Stress(Mpa)
Clearance Fit	**0**	**0**
Push Fit	**0**	**0**
Interference Fit(0.01)	**149.5**	**149.5**

Table 3.2: Tabular representation of contact pressure & radial stress for different fits at Zero Load

The results shows contact pressure development of 149.5N/mm2 at the interface. Almost equal contact pressure across the interface can be observed in the figure. The contact pressure shows joint strength. Higher contact pressure indicated higher joint strength. Few times, the joints are press-trussed to almost 80% of yield strength to increase the load carrying capacity.

3.3 Interference And External Load

Type of Fit	Radial Stress		Hoop Stress	
	180^0	90^0	180^0	90^0
Clearance Fit	25	-1	-52	198.4
Push Fit	24	-20	4.707	29
Interference Fit	0	-95	17	10

Table 3.4: Tabular representation of contact pressure & radial stress for different fits at External Loads

4. Conclusion

- For the first time, an analysis has been carried out for fits in three dimensional domain which is difficult compared to the two dimensional analysis due to convergence problems.
- Initially a two dimensional mesh is carried out and later converted to three dimensional meshing using solid185 element which is suitable for both isotropic and composite materials.
- Radial and hoop stress plots are represented across the interface between pin and the plate. In the analysis, pin is assumed as rigid. The analysis results give insight of stress distribution, contact pressure by which separation regions can be identified. Uneven contacts automatically reduce the load carrying capacity.
- The plots indicates initial higher radial stress due to interference helps in higher load carrying capacity as it induces compressive stresses in the structure. The external loads have to exceed these stresses to

put the members in tension. Tension stress is not desirable in the structure, it indicates separation and also the source for fatigue cracks.

- Also composite analysis with different orientation of the layer orientation gives insight of contact and radial stress distribution in the joints. The results indicate non-uniform contacts between the members with composites. So special care should be considered for composite usage in pin joints.
- Nonlinear distribution of contact pressure and radial stresses along with unpredicted hoop stress distribution complicates composite design in the joint regions. So special focus should be taken during composite design to provide higher compressive stresses which will increase the load carrying capacity of the joint. For certain orientation, the stress is becoming tensile which indicates separation of the joint.
- Modal Analysis is also carried out to find the dynamic stability of the structures. The results show higher natural frequencies with increased interference.
- Compared to clearance and push fits, interference fit shows higher nature frequencies indicating higher stiffness in the structure for the same mass distribution.
- Composite modal analysis results also shows depends of dynamic stability on the layer orientation. The results shows complete variation of modal results with change in layer orientation. So a proper study is important before using the composites for dynamic problems.

REFERENCES

[1]. Shigley, Joseph E., Mechanical Engineering Design, McGraw-Hill, 1977, 3 rd edition
[2]. Norton, Robert L., Machine Design – An Integrated Approach, Prentice-Hall: New Jersey, 1998, 2 nd printing
[3]. Levinson, Irving J., Machine Design, Reston Publishing: Virginia, 1978, 1 st printing
[4]. Spotts, M. F., Design of Machine Elements, Prentice-Hall: New Jersey, 1978, 5 th edition
[5]. Adams, Vince, and Askenazi, Abraham, Building Better Products with Finite Element Analysis, On Word Press: New Mexico, 1999, 1 st printing
[6]. Sopwith, D. G., "The Distribution of Load in Screw-Thread," Institution of Mechanical Engineers, Proceedings, Vol. 159, No. 45, pp. 373-383, 1948
[7]. Advances in Structural Testing, Analysis & Design, Vol. I, II & III, T.S. Ramamurthy and others, Eds., Pubs: Tata McGraw-Hill Publishing Company Limited, 1990.
[8]. Finite element determination of contact stresses in engineering problems', (B.Dattaguru, T.S.Ramamurthy & A.K.Rao), J Ae S I Vol 37(4), pp 347-355, 1985.
[9]. Analysis of interfence fit pins in composite plates', (T.S.Rama murthy), Proc. 3rd Tech. Conf on Composite matls, American Soc. for Composites & Univ. of Washington, Seattle, pp 623-632, 1988
[10]. Analysis of interference fit pins in composite plates: Nonlinear behaviour under bypass loading', (T.S.Ramamurthy), Paper 89-1231,Proc. 30th SDM Conf. (AIAA), Vol 2, pp 653-651, Mobile, AL, 1989.
[11]. Recent studies on the behaviour of interference fit pins in composite plates', (T.S.Ramamurthy), Composite Structs an Int J, Vol 13 (2), pp 81-99, 1989.
[12]. Analysis of pin joints under bypass loads', (T.S.Ramamurthy), AIAA J, Vol.28 No.10, pp 1800-1805, 1990.
[13]. Design and analysis of bolted joints in compositees', T.S. Ramamurthy and B. Dattaguru, Proc. of Indo-US Workshop on composites for Aerospace applications, Vol. II, pp69-74, 1990.
[14]. Concepts and Application of Finite Element Analysis Rober D. Cook, David S – Joh Wiely & Sons Pte. Ltd. Fourth Edition 2003.
[15]. Finite Element Procedures – Klaus-Jurgen Bathe, Prentice Hall of India Pvt. Ltd.- Sixth Edition 2002
[16]. Finite Elements in Engineering – Tirupathi R. Chandrupatla, Ashok D. Belegundu, Prentice-Hall of India Pvt. Ltd, 2003
[17]. Introduction to the Finite Element Method, Desai/Abel – CBS publishers 2002 Finite Element Analysis – C.S. Krishnamoorthy, Second Edn, TMH - 2002