



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 5, May 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

 [ijirset@gmail.com](mailto:ijirset@gmail.com)

 [www.ijirset.com](http://www.ijirset.com)

# Fatigue Analysis of Spline Coupling in Wind Turbine Rotor

**B. Jayaprakash<sup>1</sup>, Mahadeva<sup>2</sup>, MahammadHaareeshs<sup>3</sup>, Mahammed Usman<sup>4</sup>, Naveen Kumar K<sup>5</sup>**

Assistant Professor, Department of Mechanical Engineering, Ballari Institute of Technology and Management, Ballari,  
Karnataka, India<sup>1</sup>

U.G Students, Department of Mechanical Engineering, Ballari Institute of Technology and Management, Ballari,  
Karnataka, India<sup>2,3,4,5</sup>

**ABSTRACT:** Spline couplings are one of the most often used methods for connecting two spinning shafts in situations in which it is necessary to convey a great deal of power. These components are responsible for motion transmission by using a predetermined number of engaging teeth. Because of the varying amplitude loadings and relative sliding, these teeth experience both fatigue and wear over time. In industrial transmissions, splines transmit more torque for their size than any other type of coupler or joint. If they operate with a relatively small shaft diameter, a common type of failure in this case is due to the shaft shear stresses. In general, splines transmit more torque than any other type of coupler or joint. When it comes to high power transmissions, which have become increasingly popular over the past few decades as a result of improvements in the performance of machines, the shaft and hub are designed using a classical formula that takes into account both the static and fatigue points of view. As a result, the issue of sudden failures caused by shear stresses is virtually non-existent. The involute spline hub connection under pure torsion loading case aims to find the load distribution along the length of spline and localized stress area on teeth. Spline shaft for transmitting a torque is used. Properly aligned connection without sliding and angular misalignment is used. When the shaft is connected to a pure and steady torque load, then the connection is under pure torsion loading condition. In pure torque transmitting case the spline teeth are under shear stress. In this paper the location for the stress along the spline length for partial contact length and the load distribution along the length of spline teeth is evaluated. Load distribution along the length of spline is measured. The setup consists of spline connection mounted on the fixture. In-volute spline geometry is defined, as the involute spline geometry have a more load carrying capacity compared with the rectangular and trapezoidal spline geometry.

**KEYWORDS:** Fatigue Analysis of Spline Coupling in Wind Turbine Rotor NX12 software, ANSYS work bench software.

## I. INTRODUCTION

Since its invention by Sir Frank Whittle in 1937, the jet engine, also known as the gas turbine engine, has seen a steady rise in usage for the purpose of flight propulsion. This is because it has a favorable thrust to weight ratio, making it more efficient than alternative forms of power. The Rolls-Royce gas turbine aircraft engine, which is widely deployed in civil aviation and is produced by the company. The engine's core consists of compressors and turbines, and the three shaft design allows for independent connections to be made between the low, intermediate, and high pressure sets. When compared to conventional designs with two shafts, this makes it much simpler to scale the shafts to meet the specific air frame requirements, and it also enables the most efficient rate of shaft rotation. The use of a single shaft for each pressure set is impractical due to the shaft lengths that would be required and the difficulty that would be associated with the assembly and reassembly of the modules that comprise the full pressure set. It is common practice to use a spline coupling as a joint for the purpose of transferring torque from one shaft to another. It is an easy feature to assemble and disassemble, in addition to being able to accommodate axial thrust and axial misalignment, and it is a compact feature. The low-pressure (LP) coupling, which is also the one that is the most heavily loaded, is the primary focus of the work that is being done for this thesis. Because the spline coupling is so important to the engine's overall health, conservative design choices are unfortunately required to guarantee the safety of the passengers. Because of the intense level of competition in the aerospace industry and the ongoing need to lessen the amount of fuel that is burned by flight carriers, there is an ongoing demand for improved performance in gas turbines.

## II. LITERATURE REVIEW

This chapter examines the current state of fretting fatigue (ff) knowledge. First, a brief history of conventional fatigue (fatigue without fretting) is presented. There is an introduction to fretting, followed by a discussion of the key analysis techniques that can be used to solve the fretting problem. The approaches to fracture mechanics and wear are then discussed within the context of fretting fatigue. The outcomes of numerical analyses of a complex aero engine spline coupling are then examined. The concept of representative specimens is applied to spline geometry, along with specifics on the experimental setups used. The paper concludes with a summary of the key advancements required to comprehend fretting fatigue in spline couplings, which will be addressed. Numerous engineering failures have caused catastrophic destruction and fatalities. Fatigue, which is the localised progressive damage to a material caused by cyclic stresses or strains and can lead to cracks and eventually fractures, is the leading cause of mechanical failures. The field of fatigue research is expansive, and numerous factors contribute to fatigue failure.

## III. METHODOLOGY

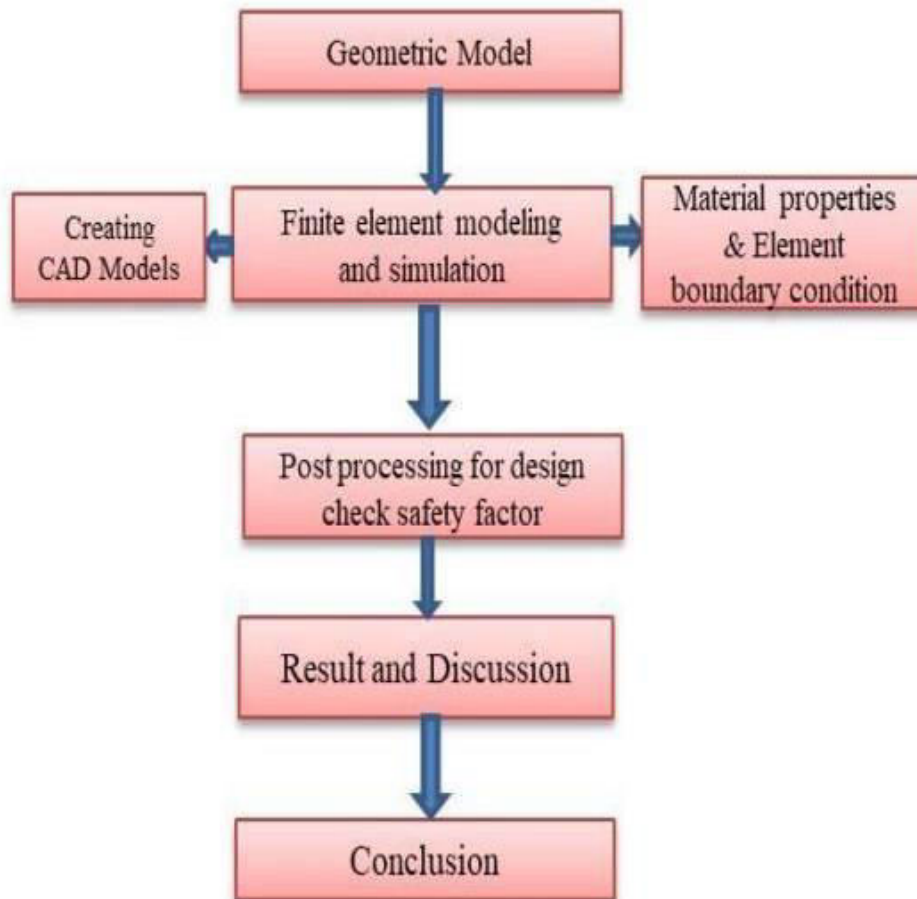


Fig: (4.0) Flow chart

Step-1:- Modeling

Step 2:- Description of continuum (Structure). Step3:- Selection of proper interpolation mode Step 4:- Derivation of element stiffness matrix

Step 5:- Assemblage of element equations to obtain the equilibrium equations Step- 6: Enforcing the boundary conditions

Step 7:- Solution of system equation to find nodal values of displacement Step8:- Computation of element strains and stresses.

#### IV. OBJECTIVES

- Conducting a linear static analysis on the spline connection between a shaft and a sleeve. Employing Ansys Workbench as the application software.
- Determining the modes and natural frequency between the shaft and the sleeve
- Development of a FEM model to demonstrate the spline tooth width in the axial direction in order to distribute the load uniformly across the structure. A range of tooth shapes, sizes, and variances are the subject of current research
- Using the finite element approach to evaluate the fatigue life of the spline coupling.

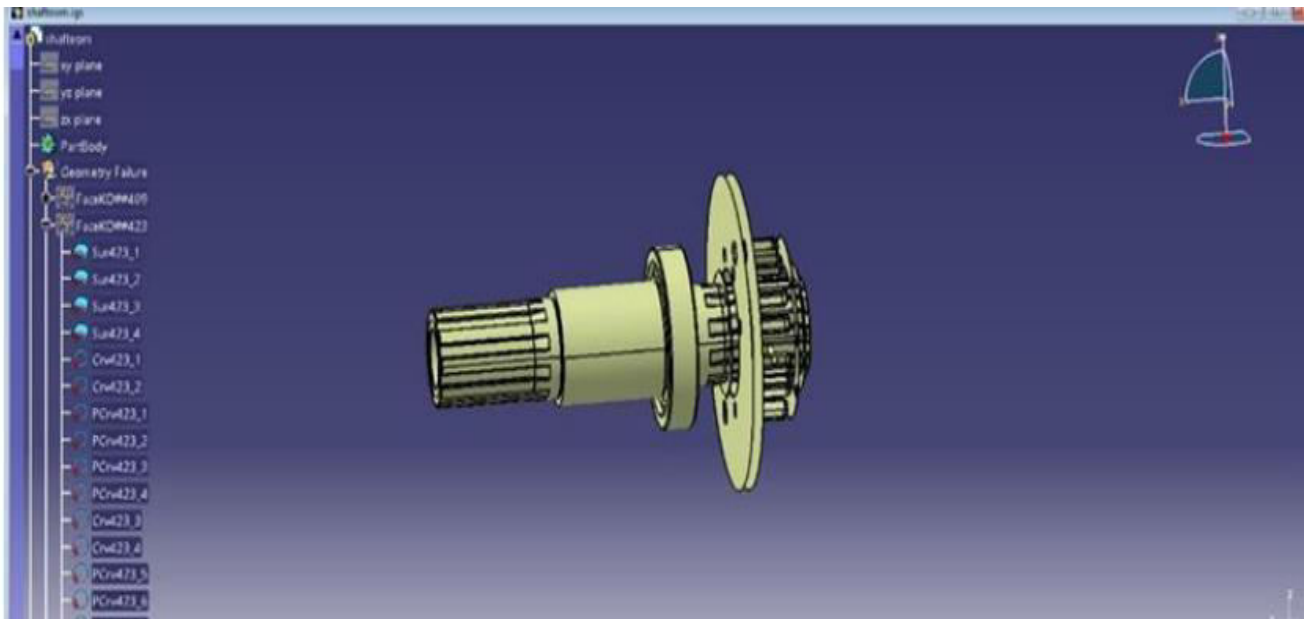


Fig 1: GEOMETRIC MODEL

Design representative spline coupling geometries for each material (Metal; Nonferrous Metal; TitaniumAlloy).

#### V. RESULTS

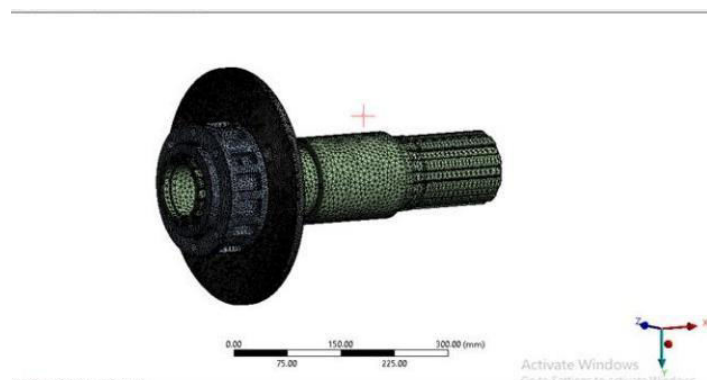


Fig 2: MESH MODEL

Define mesh settings and generate meshes for spline coupling geometries. conduct mesh refinement studies for convergence.



Fig 3: MAXIMUM PRINCIPAL STRESS

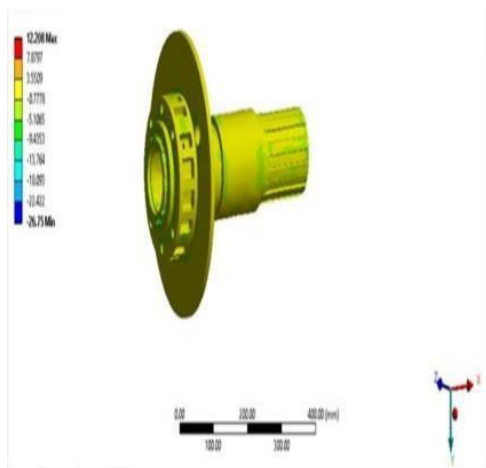


Fig 4: MINIMUM PRINCIPAL STRESS

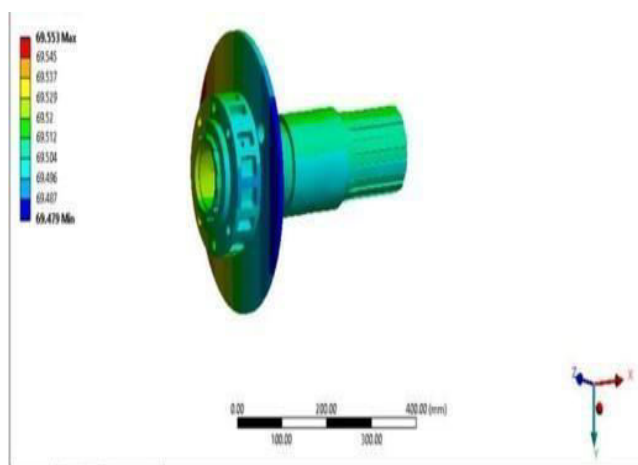


Fig 5: TOTAL

DYNAMIC MODE GRAPH



Graph 1

Tabular Data mode

SL	MODE	Frequency[Hz]
1	1.	494.21
2	2.	498.28
3	3.	1908.4
4	4.	2382.2
5	5.	2393.3
6	6.	2503.4

DYNAMIC ANALYSIS

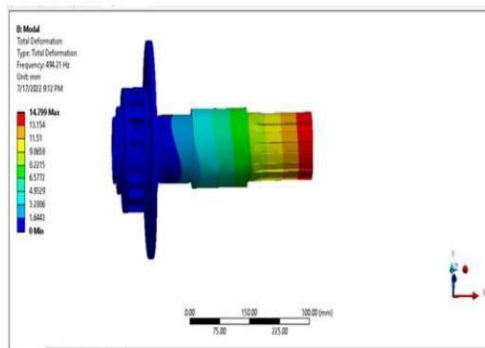


Fig 6: Mode 1

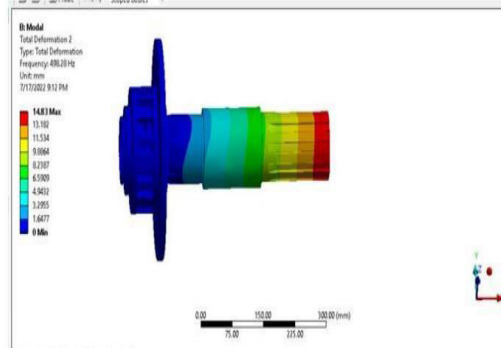
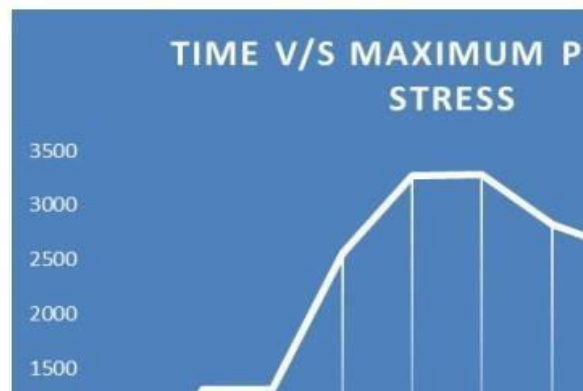


Fig 7: Mode 2

ANALYSIS GRAPHS



Graph 2



Graph 3



Graph 4



Graph 5

VI. CONCLUSIONS

The analytical formulation described in this report provides much of the same information as modern gearbox design software, plus estimation of spline safety factors. By its nature, the analytical formulation provides greater insight into the effect of the spline coupling design parameters upon the spline performance and resulting safety factors than the other approaches. Solutions can be calculated two orders of magnitude faster than higher fidelity models, making it very useful for early design stage parametric studies. And is publicly available as a stand-alone

executable program called the Gear Spline Coupling Program (Gear SCouP). When the spline is in perfect alignment, the load is shared equally across all spline teeth and the tooth load distribution has a parabolic shape. When the spline is misaligned, the number of teeth in contact decreases and the maximum tooth load increases sharply. Torque affects the spline load share, maximum tooth load, and safety factors. It is important to evaluate the spline design within the entire torque spectrum. Crowning improves the load share factor and maximum tooth load; however, tooth contact stresses can increase and the associated safety factors can decrease. Carburizing and induction hardening the tooth flanks and roots are the best practices to enhance the spline strength among those studied, though the risks of fretting corrosion and scuffing are not yet addressed in the analytical model.

## REFERENCES

1. Z.L. Mahri, M.S. Rouabah, "Calculation of dynamic stresses using finite element method and prediction of fatigue failure for wind turbine rotor" Wseas Transactions On Applied And Theoretical Mechanics, Issue1, Volume 3, January 2008.
2. Philippe Giguere and Selig, "Blade Geometry Optimization For The Design Of Wind Turbine Rotors" AIAA-2000-0045.
3. M. Jureczko, M. Pawlak, A. Mezyk, "Optimization of wind turbine blades", Journal of Materials Processing Technology 167 (2005) 463–471.
4. Wang Xudong, et al., "Blade optimizations for wind turbines", Wind Energy. 2009; 12:781–803, Published online 29 April 2009 in Wiley Interscience.
5. F. Zahle, N. N. Sørensen, and J. Johansen. Wind turbine rotor-tower interaction using an incompressible overset grid method. Wind Energy, 12:594–619, 2009.
6. A. Bechmann, N. N. Sørensen, and F. Zahle. CFD simulations of the MEXICO rotor. Wind Energy, 14:677–689, 2011.
7. Y. Bazilevs, M.-C. Hsu, I. Akkerman, S. Wright, K. Takizawa, B. Henicke, T. Spielman, and T. E. Tezduyar. 3D simulation of wind turbine rotors at full scale. Part I: Geometry modeling and aerodynamics. International Journal for Numerical Methods in Fluids, 65:207–235, 2011.
8. K. Takizawa, B. Henicke, T. E. Tezduyar, M.-C. Hsu, and Y. Bazilevs. Stabilized space–time computation of wind-turbine rotor aerodynamics. Computational Mechanics, 48:333–344, 2011.
9. K. Takizawa, B. Henicke, D. Montes, T. E. Tezduyar, M.-C. Hsu, and Y. Bazilevs. Numerical-performance studies for the stabilized space–time computation of wind-turbine rotor aerodynamics. Computational Mechanics, 48:647–657, 2011.
10. Y. Li and P. M. Carrica K. J. Paik, T. Xing. Dynamic overset CFD simulations of wind turbine aerodynamics. Renewable Energy, 37:285–298, 2012.
11. N. N. Sørensen and S. Schreck. Computation of the National Renewable Energy Laboratory Phase-VI rotor in pitch motion during standstill. Wind Energy, 2012. doi:10.1002/we.480.
12. F. Scheurich and R. E. Brown. Modelling the aerodynamics of vertical-axis wind turbines in unsteady wind conditions. Wind Energy, 2012. doi:10.1002/we.532. Fatigue Analysis of Spline Coupling in Wind Turbine Rotor Page 51
13. R. Chow and C. P. van Dam. Verification of computational simulations of the NREL 5 MW rotor with a focus on inboard flow separation. Wind Energy, 2012. doi:10.1002/we.529.
14. P. Stein and K. Beucke M.-C. Hsu, Y. Bazilevs. Operator- and template-based modeling of solid geometry for isogeometric analysis with application to vertical axis wind turbine simulation. Computer Methods in Applied Mechanics and Engineering, 213–216:71–83, 2012.
15. E. Lund and J. Stegmann. On structural optimization of composite shell structures using a discrete constitutive parametrization. Wind Energy, 8:109–124, 2005



INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details