International Journal of Advanced Technology in Engineering and Science
Vol. No. 09, Issue No. 04, April 2021
www.ijates.com
ijates
ISSN 2348 - 7550

Numerical Investigation of Gas Turbine blades with Dampers for Reducing Vibrations

Prasath M S, Sivaraj G, Lakshmanan D, Vadivelu P

Department of Aeronautical Engineering, Bannari Amman Institute of Technology,
Sathyamangalam-638401, prasathms90@gmail.com

ABSTRACT

*A gas turbine is an internal combustion engine that can convert a fuel to useful mechanical energy. It has numerous moving parts and among them the turbine blades are key components of turbo-machinery. During its operation the blades are subjected to various static and dynamic loads which alter the blade performance. In order to avoid the blade failure, the vibrations has to be eliminated or reduced in turbo machines***.** *Blade failure is one of the most common structural imperfection and cause catastrophic structural failure. This paper deals about the reduction of vibration in turbine blades. The main reason for vibration is the centrifugal loads acting in the turbine blades. This load creates a dynamic motion along the blade length which causes the blade vibration. This vibration can be reduced by using a damper between the blades. Some of the dampers like flat damper, wedged damper, dog bone damper were selected. The structural analysis has been conducted for the turbine blades with and without these dampers for different materials. Among all these dampers, the flat damper performs well in reducing the vibrations in turbine blades and it is suggested. In this paper the NACA series airfoil was selected (S1210) for modelling the turbine blades. Materials with different properties were selected for analysing the turbine blades such as mild steel, nickel, titanium and tungsten. The model was created using CATIAV5 software and further the analysis was carried out using ANSYS MECHANICAL APDL software. The deformation results were plotted in graphs to compare the dampers and materials used which can increase the life of the turbine blades.*

Keywords: Turbine blades, dampers, vibrations, blade failure, materials.

I. INTRODUCTION:

A gas turbine engine is the heart of an aircraft. It generates propulsive power to move the aircraft forward. They can operate at high RPM with high temperatures and this causes additional thermal stress on a gas turbine blade.A gas turbine engine has rotors with multiple stages and each stage of the rotor has a multiple numbers of blades.Due to their high operational range of temperature and speed, these rotor blades experiences high thermal stress. This causes a turbine blade to have high chance of structural damage. The damage on your single blade can totally destroy or may cause a catastrophic failure in engine. This is a worst nightmare in the aero industry as it may lead to a huge disaster or even an air crash.

Due to the continuous operation of gas turbine, the turbine blades experiences a type of *fatigue* called *blade fatigue.* This is caused by the stress and vibration occurring in it. This fatigue can be reduced by adding the dampers in between the turbine blades.Adding a damper between the blades may reduce the vibration produced in the blades (as it may affect the natural frequency of the dates). So in this paper it is proposed to have an advantage in having dampers in between the turbine blades. The turbine blade with and without dampers are model and analysed by using numerical simulations. Theresults of the simulations areimplemented with different materials and different types of dampers were also proposed.

The existing turbine blade does not have any dampers in between them. In this paper dampers were placed in between to turbine blades and the effect of these dampers were studied. Dampers with two different configurations were design and will be studied under modal analysis. The modal analysis studies gives natural frequency ranges and helps to study about the vibration and the formation that can occur in turbine blades.The selection of right material plays a major role in turbine blade design and analysis. Because of the gas turbines operate at high temperature and speeds, the gas turbine blades must withstand them. It should not damage mechanically. The efficiency of the turbine depends on the type of material selected for the gas turbine blade. They extract the mechanical power (energy) from the hot expanded gases of the combustion chamber. Usually, high temperature materials like Titanium, Nickel, special Steel and other super alloys were used in themanufacturing of gas turbine blades. In this paper, materials like Steel, Nickel, Titanium and Tungsten blades were selected to carry out the numerical simulation.

A damper is a device that reduces the vibration created by the particular to which it is attached. Usually the dampers are used in moving mechanical parts. In turbine also the dampers were used to reduce the mechanical vibrations that are caused due to its high speed operations. Many types of dampers are there and in this paper two types of dampers were analysed with different materials to find which type of material with a particular damper shape can withstand load and has less deformation. Based on the modal analysis, deformation of turbine blades were found with less defamation. Two types of dampers - flat Dumper and wedge damper were used to carry out the optimisation of turbine blades. The dampers are usually attached under to turbine blades. Theyabsorb the centrifugal force created in turbine blade and dissipate it and then dampens the vibration produced.

The optimisation process starts with the selection of right airfoil for the turbine blade as it must be efficient enough to extract the energy from hot burnt gases. After that selected dampers were attached with the turbine blades and the numerical simulation was carried out for those blades with different materials. The model analysis was performed to find the deformation produced and the results were compared.

II. LITERATURE SURVEY:

Bhupendra Et al. studied the frequencies of turbine blade with different modes using Ansys. Due to the complexity in turbine blade design Sivakumar Et al. designed turbine blades using Ansys. The same procedure was followed in this paper also. Pedaprolu Venkata Vinod Et al. designed the gas turbine blade using Catia. Since it is the powerful modelling tool, same procedure was followed in this paper. Nagabhushan Rao Et al. conducted a series of simulations on turbine blades with different materials. Since the turbine blades are working at high temperatures the selection of material for the blade plays an important role. Nickel based alloys were used for turbine blade and based on his paper the materials were selected for this paper also. K. Y. Sanliturk Et al. attached dumpers to the turbine blades and analysed the deformations occurring in it and differences it made. Based on these literature surveys, the design, material selection and analyses part of this paper is carried out.

III. METHODOLOGY:

The designing process starts with the selection of airfoil profile for the turbine blades. Since they operate at higher speeds the airfoil profile selection is very important. In this paper NACA S1210 airfoil was chosen for the modelling of turbine blades. It is one of the common types of aerofoil selected for turbine blade design.

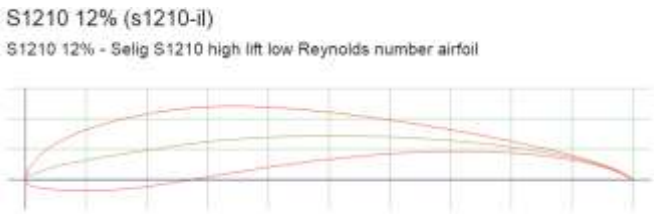

Fig.1: NACA S1210 Airfoil

CATIA is a good CAD modelling tool and it was selected for modelling the turbine blades. The selected NACA S1210 airfoil coordinates were imported and based on the coordinatesturbine blades were designed. Since different dampers were analysed in this paper, the turbine blades with different damper shapes were modelled. The length and width of the blade is 300mm and 100mm each. The distance between two blades is given as 150mm. based on these dimensions, the turbine blades were modelled using CATIA software.

Fig.2: Turbine blades

For simplicity, only a pair of turbine blades were analysed and that is enough to study about the deformation and deflection generated in it. Basically three cases of turbine blades were designed for the numerical simulations (i) turbine blade without damper, (ii) turbine blade with flat damper, (iii) turbine blade with wedge damper. Depending upon the damper used, the deformation will be varying in these models.

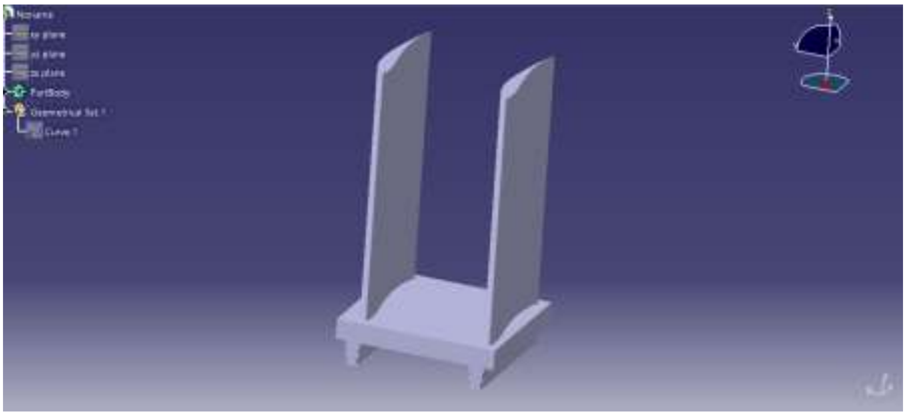

Fig.3: Case-1: Turbine Blade Without Damper

A flat damper is like a flat surface located at the root of turbine blade it is simply like extending the thickness of root portion in which the turbine blade is mounted. The dimension of this damper model is given below.

Fig.4: Case-2: Turbine Blade with Flat Damper

Similarto the location of the flat damper, the wedge-shaped damper is also located at the root portion of the turbine blades. As the name suggests the damper is wedge shaped and connecting the two turbine blades. The dimension of this damper model is given below.

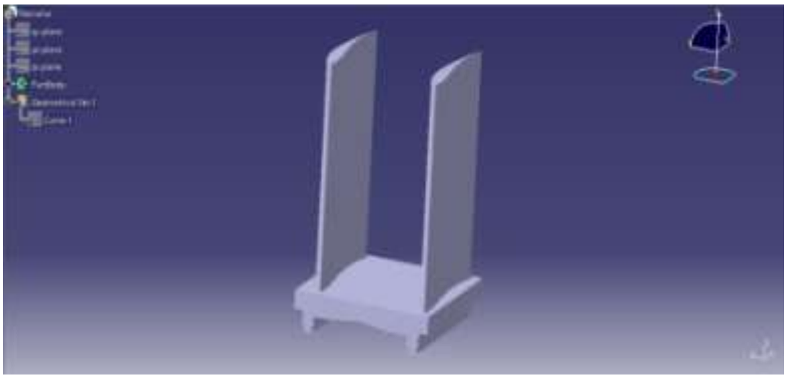

Fig.5: Case-3: Turbine Blade with Wedge Damper

IV. RESULT AND DISCUSSIONS:

The analysis of turbine blades and dampers start with the material selection. Different materials has different properties (from the literature survey the metals were selected) Steel Nickel, Titanium and Tungsten are the materials choices for this paper. The analysis part was carried out using Ansys Mechanical APDL and this tool helps us to define material the results can also be visualised clearly.

For the designed dampers different material properties were given and analysed in Ansys. Since only the deformation and deflection is concerned, the models were analysed as modal analysis. The models are analysed for different modes and frequencies with the different material properties. The analysis of models start with selecting a particular damper and applying the mode frequencies with different materials as given below

Table.1: Material Properties

Sl.No	Material	Young's Modulus (GPa)	Density kg/m^3	Poisson's Ratio
1	Steel	200	8050	0.30
2	Nickel	190	8900	0.31
3	Titanium	110	4506	0.32
4	Tungsten	340	19250	0.28

Case-1: Turbine Blade without Damper

In case-1, a set of turbine blades without dampers were analysed for different materials.

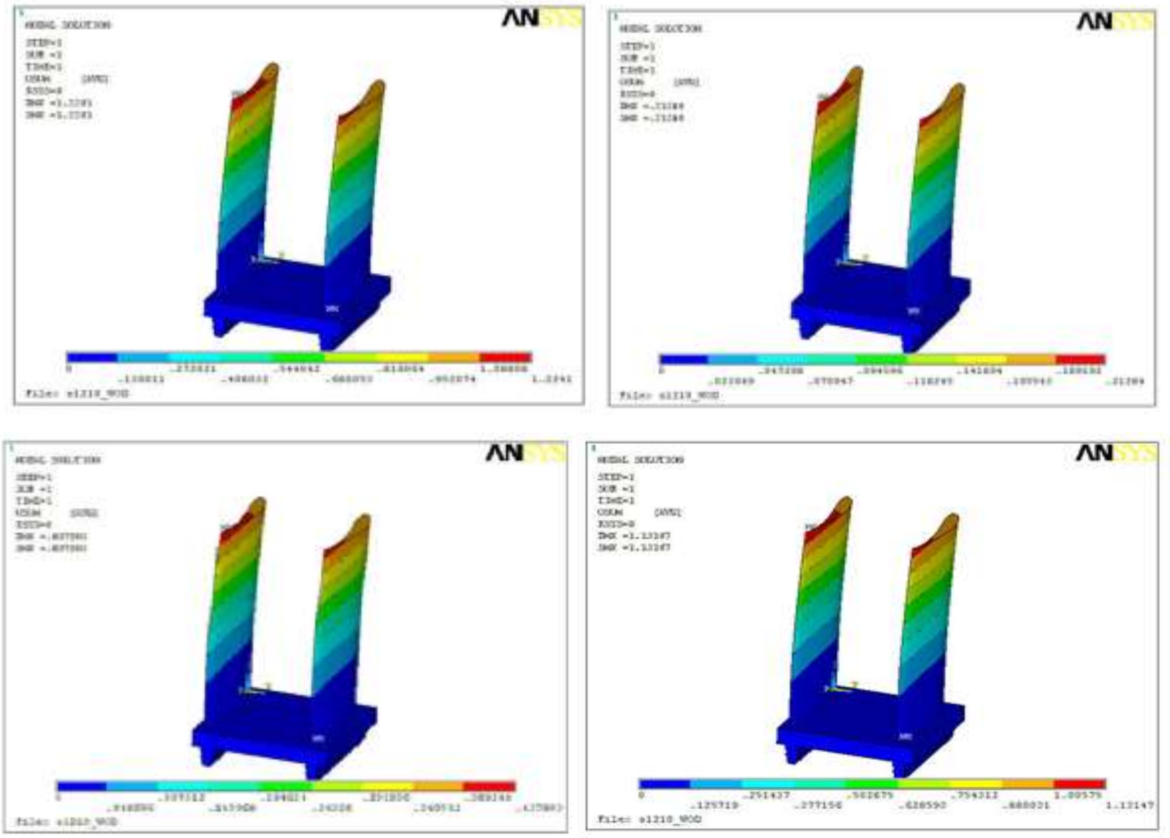

Fig.6: Case-1: Deflections of Turbine Blade without Damper for Different Materials

At first the Steel was considered for the analysis. Since it has low material properties than the others, the turbine blade deforms up to 1.22416mm and similarly for the Nickel it deforms about 1.21264mm. Further the same model has been analysed for Titanium and Tungsten. The model had informed about 1.13147mm and 0.43790mm respectively. These values clearly show that Tungsten material has less the formation comparing to all the other materials for this model without damper.

Case-2: Turbine Blade with Flat Dumper

In case 2, a flat damper has been placed in between the two turbine blades and modal analysis has been carried out on this model for different materials similar to case1.

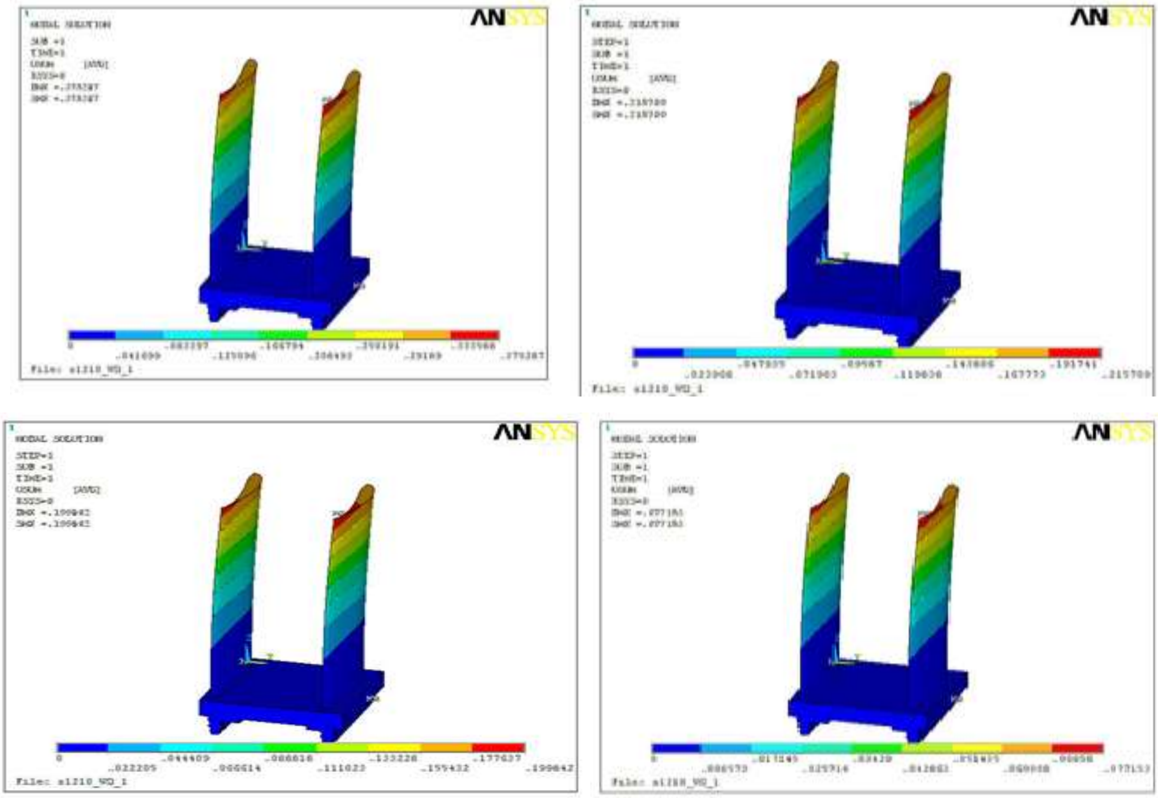

Fig.7: Case-2: Deflections of Turbine Blade with Flat Damper for Different Materials

First Steel was chosen for the modal analysis and its shows 0.37526mm of deformation in the damper which is considerably very low comparing to the model without damper as in case 1. Similarly for Nickel, itdeformed about 0.21570mm. Further the same model has been analysed for Titanium and Tungsten and the model hasdeformed about 0.19964mm and 0.07715mm respectively. These values clearly show that the model with damper has less deformation comparing to the model without the damper in it.

Case- 3: Turbine Blade with Wedge Damper

Case-3 is also similar to case-2 to but the flat damper is replaced with a wedge-shaped damper. Similar to the above two cases the model has been analysed with all four different materials. In case 3, a flat damper has been placed in between the two turbine blades and modal analysis has been carried out on this model for different materials similar to case-2.

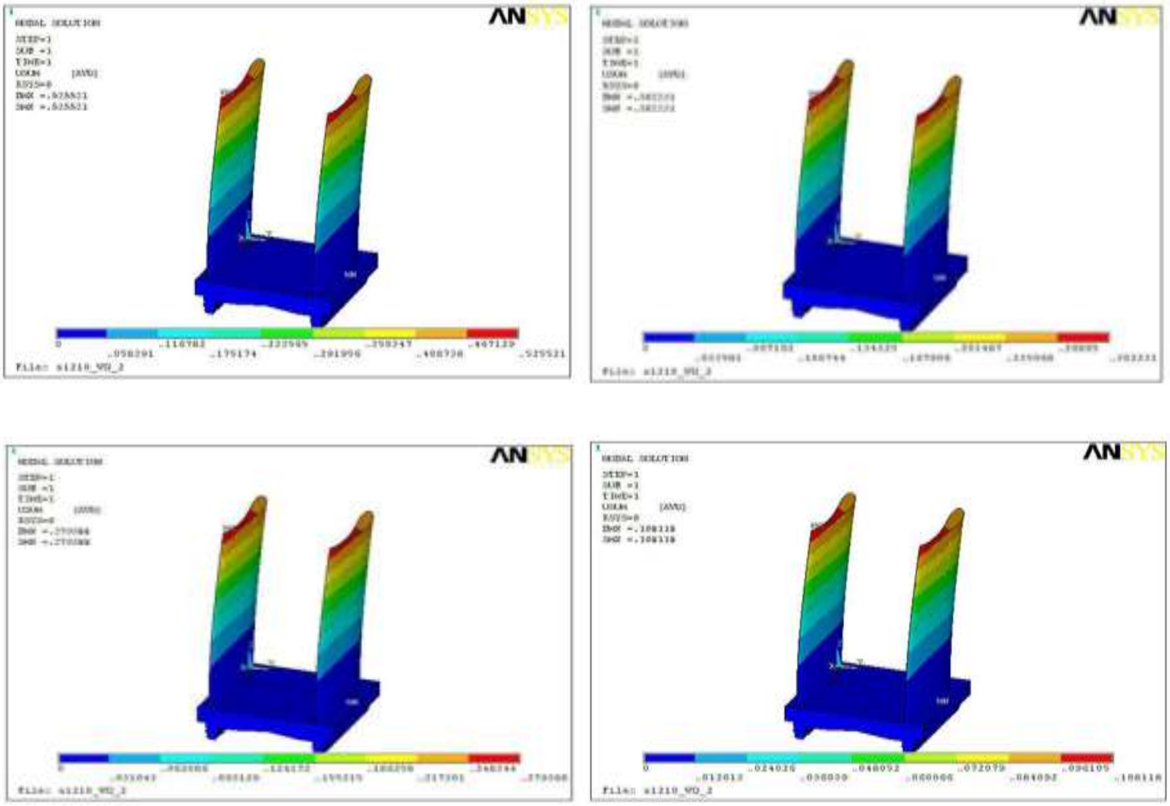

Fig.8: Case-3: Deflections of Turbine Blade with Wedge Damper for Different Materials

First Steel was chosen for the modal analysis and its shows 0.52552mm of deformation in the damper which is considerably higher comparing to values in case 2. Similarly for Nickel, it deformed about 0.30223mm. Further the same model has been analysed for Titanium and Tungsten and the model has deformed about 0.27936mm and 0.10611mm respectively. These values clearly show that the model with wedge shaped damper has more deformation comparing to the model with the flat damper in it.From the results it is clear that the models with damper with stand more deflection than the model without the damper.

From the above analysis it is clear that the damper plays a major role in the deformation of turbine blades. Here, it shows that the deformation over the surface of the turbine blades was analysed in modal analysis for the cases without and with dampersalong with different of materials. The results are comparedfor different types of materials with two types of damper (flat and wedge) and without dampers which are having different deformations from the above analysis. Materials like steel, nickel, titanium and tungsten were used to compare the dampers as flat and wedged. The steel hasless vibration in flat damper (0.3756mm) as well as wedged damper (0.0.52552mm) when compared to without damper (1.22410mm). But steel does not have great structural strength for turbine blades. Titanium has a small vibration in flat damper (0.19964mm) as well as wedged damper (0.27936mm) when compared to without damper (1.13147mm). Titanium has good corrosion resistant but it has production cost and high reactivity. Tungsten has a small vibration in flat damper

(0.07715mm) as well as wedged damper (0.10611mm) when compared to without damper (0.43790mm). Tungsten is an intrinsically brittle and hard material. Nickel has a small vibration in flat damper (0.21570mm) as well as wedged damper (0.30223mm) when compared to without damper (1.21264mm). Nickel has good heat resistant, good corrosion resistant and low expansion. A comparison of values from different materials with dampers and without dampers is given below.

Table.2: Comparison of Result

Types Of Dampers	Materials			
	Mild Steel (mm)	Nickel (mm)	Titanium (mm)	Tungsten (mm)
Case-1	1.13147	1.22410	1.21264	0.43790
Case-2	0.19964	0.21570	0.37526	0.07715
Case-3	0.27936	0.30223	0.52552	0.10611

V. CONCLUSION

From the analysis, it is found that the model without damper has larger range of deformations in turbine blades when compared to the other two models with dampers (flat and wedged). Nickel-based alloys are selected as material choice for gas turbine blades because it has good heat resistant, good corrosion resistant and low thermal expansion. In this paper, flat damper is good in reducing the vibrations compared to other damper model. It is concluded that the turbine blades have less vibration when the dampers were used. Especially when the flat type dampers wereused when compared to turbine without damper.

REFERENCES

[1] Csaba G., “Friction Damping of Turbine Blade Vibrations Using a Microslip Model”, Journal of Machine Vibration, 1995, Vol. 4, pp. 2-7and LiU-Tek-Lic-1995:09, ISBN 91-7871-507-5

[2] Csaba G., Andersson M., Optimization of Friction Damper Weight, Simulation and Experiments, ASME TurboExpo ‘97, Orlando, Florida USA, June 2-5 1997, paper 97-GT-115

[3] Afolabi, d., 1986, “Natural frequencies of Cantilever Blades with resilient Roots”, J.Sound and Vibration, vol 110, No. 3,pp.429-441

[4] Rahul A. Phadke., “A Microslip Superelement for Frictionally-Damped Forced Response Predictions”, Ph. D thesis, University of Cincinnati, 2002

[5] W. Sextro, “Dynamic contact problems with friction”, splinger, 2002(Group U of Tech. Institute of Mechanical, Austria), 1.2 review

[6] S. Narasimha , G. Venkata rao and S. Ramakrishna,. “Dynamic analysis of a turbine blade without and with damping plate using finite element method”, proc. of the National Conference on Emerging Trends in Mechanical Engineering, July 1-2, 2009, SNIST, PP.99-102

[7] P.V. Ramaiah and Dr. G. Krishnaiah , “ Modelling and Analysis of contact region of the friction damper used for gas turbine blade vibration control-A microslip approach”, IE (I) Journal-MC

[8] Stuart Moffatt, “Blade forced response prediction for industrial gas turbines part I: methodologies”, International Gas Turbine & Aero engine Congress & Exhibition June 16-19, 2003, Atlanta, Georgia, USA.

[9] Avinash, V.Sarlaskhar, “Blade pro an Ansys-based turbine blade analysis system”, Impact Technologies, LLC, and Rochester, NY 14623, U.S.A.

[10] Ewins, D.J.Imregun, “Vibration modes of packeted bladed disks”, transactions of the ASME, Vol. 106 pp175-180.

[11] Genta, G, “Dynamics of Rotating Systems”, Springer ISBN 978-0-387-20936-4. [5] Rao, J. S, “Natural frequencies of Turbine Blading – A survey”, Shock and Vib.Dig. 5(10), P

[12] M. L. J. Verhees, “Experimental Modal analysis of a gas turbine blade” Technische Universite it Eindhoven .2004

[13] J. Hou and B.Wicks, “Root flexibility and untwist effects on vibration characteristics of gas turbine blade” Air Vehicles Division Platforms Sciences Laboratory, Defence Science & Technology DSTO- RR-0250, Australia.2002