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Modeling and Analysis of Rotating Seal and Friction Damper; Calculation of Damper Stiffness

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Abstract : ***In this paper modeling of rotating seal and friction damper is explained using NX7.5 and ANSYS130x64 software. Modeling of any component is very important in analysis of the component. Analysis of rotating seal and damper is carried out using ANSYS130x64 to calculate stiffness of friction damper. Various authors explained methods to calculate stiffness of friction damper. In this paper a method is proposed to calculate stiffness of friction damper.***

Keywords

Friction damper, Rotating seal, Damper stiffness and damper circumferential growth

INTRODUCTION

Frictional forces arising from the relative motion of two contacting surfaces are a well-known source of energy dissipation. Sometimes friction is considered as an unwanted effect of the design. Dry friction resists relative motion of two solid surfaces in contact. The two types of dry friction are “static friction” between nonmoving surfaces and “kinetic friction” (sliding or dynamic friction) between moving surfaces. In applications such as turbo machinery bladed disks and rotating seals, where structural damping is negligible, dry –friction damping has been widely used to reduce the resonant response of the blades so as to limit the occurrence of wear and premature failure. Having dry friction in the system complicates the dynamic analysis of the system due to its nonlinear nature. Two type of friction damper modeling, namely, macro-slip model and micro slip model are used for such studies.

- Macro slip model assumes the entire friction surface as either slipping or stuck. It is an extensively used method due to its mathematical simplicity.
- In more realistic micro-slip model, the entire friction surface is modeled as an elastic body, allowing local slipping in the friction element without gross slip. This allows obtaining damping even in the absence of gross slip

The early research in this area includes the study by E J Berger (2002) who explained about friction modeling of dynamic system. He concluded that the system model and friction model are fundamentally coupled, and they cannot be chosen independently.
Later W. Chen and X. Deng (2005) explained about structural damping caused by micro slip along frictional interfaces at bolted joint. In addition to above George Jureaj Stein and Raduz Zahoransky et al. (2007) proposed a method for analysis and simulation of a general single degree freedom oscillatory system with idealized linear viscous damper and dry friction. In same year E. Chatelet and G. Michon, et al. (2007) proposed a method for choosing the most appropriate contact model from several models, by comparing their efficiency for predicting hysteretic behavior in different applications. Later Christian M. Firrone (2008) has done study performed on the forced response of a mock up system which simulates the flexural behavior of two turbine blades with an interposed under platform damper. In addition to above Daniel J. Dickrell III and W. G. Sawyer (2010) proposed a method to calculate lateral contact stiffness of an elastic foundation. More recently K. Asadi and H. Ahmadian et al. (2012) proposed a procedure to determine stick–slip transition under single-harmonic excitations is derived. The analytical model is verified using experimental vibration test responses performed on a free-frictionally supported beam under lateral loading.

In this paper a model is developed and static analysis is carried out to obtain stresses and response of rotating seal. In addition to analysis of seal damper model shear stiffness of friction damper is calculated.

Modeling of Rotating Seal and Damper

- UnigraphicsNX7.5 is an advanced high-end CAD/CAM/CAE software package developed by Siemens PLM Software, used to build the geometric model of seal damper
- ANSYS13 is an engineering simulation software (computer-aided engineering, or CAE) developer. ANSYS offers engineering simulation solution sets in engineering simulation that a design process requires, used to create FE model and solve static and modal analysis

Procedure for modeling of seal and damper

- ➢ First create the 2D sketch of seal damper using unigraphicsNX7.5 as shown in figure 1.
- ➢ Create .iges file and export it in ANSYS13 and create area using lines.
- ➢ Mesh 2D model of seal damper using PLANE25 and COMBIN14 element type.
- ➢ PLANE25 is an Axisymmetric –Harmonic 4-node structural solid Element. The element is defined by four nodes having three degree of freedom per node.
- ➢ COMBIN14 element has longitudinal or torsional capability in 1D, 2D, and 3D applications. The longitudinal spring damper option is a uniaxial tension-compression element with up to three degree of freedom at each node.

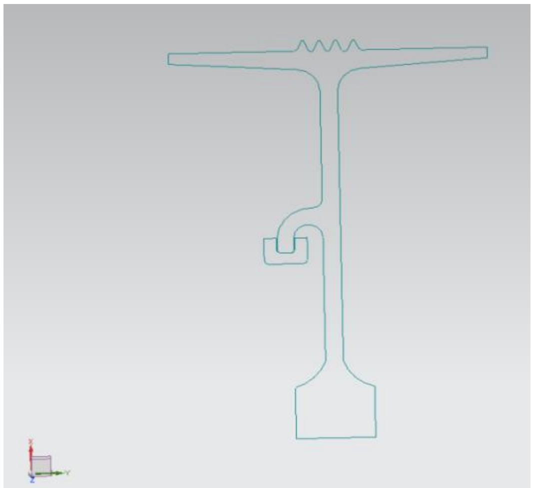

Figure 1 2D sketch seal damper model

- ➢ Get 3D model revolve 2D model about axis (As seal is axisymmetric 360˚ revolution is carried out and the damper is non-axisymmetric hence the 2D model is revolved for 358˚) as shown in figure 2.

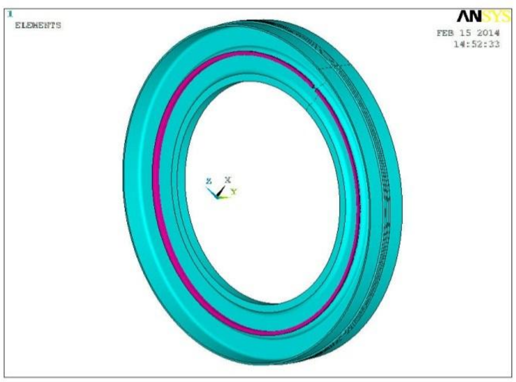

Figure 2 3D seal damper model

- ➢ Mesh 3D model using SOLID45 element using sweep command.
- ➢ SOLID45 element is used for the 3-D modeling of solid structures. The element is defined by eight nodes 3-DOF at each node

Results and discussion

Static analysis of 2D seal and 3D seal model is carried out to obtain stresses and response. Comparison of 2D and 3D analysis are shown in table 1, which are shows that results for 2D and 3D analysis are approximately same.

Contact surface is created between seal damper interface using contact174 and target170 element using ANSYS. Reflective symmetry model of seal damper is solved to get circumferential growth of damper and shear stresses at the interface of seal damper model.

Table 1

Comparison of 2D and 3D seal model static analysis results

2D static analysis results			
	Radial	Axial	Circumferential
Displacement (in)	0.016	0.13E04	
Stress (ksi)	20.283	45.254	101.883
3D static analysis results			
	Radial	Circumferential	Axial
Displacement (in)	0.019	0.23E-06	0.46E-04
Stress (ksi)	20.188	102.232	45.473

Contour plot of circumferential growth in damper is shown in figure 3 and shear stress plot of damper is shown in figure 4. Using above mention figure 3 & 4 stiffness of friction damper is calculated.

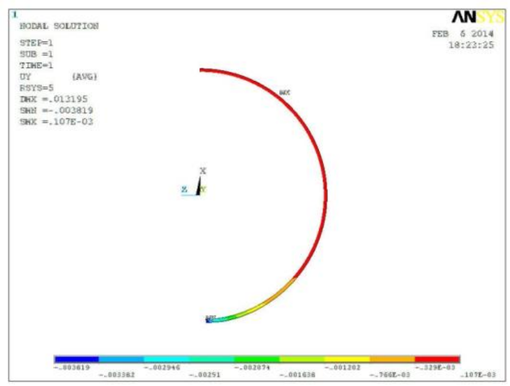

Figure 3 Circumferential growth plot of damper

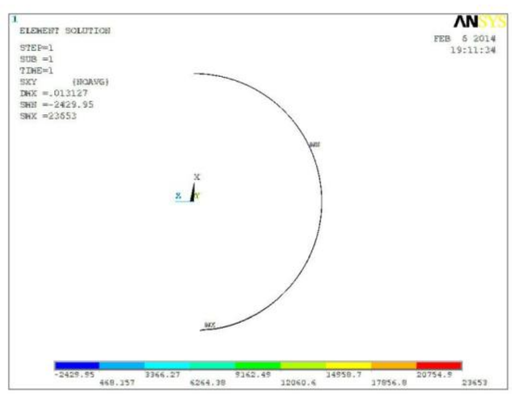

Figure 4 Shear stress plot of damper surface

Shear stress Sxy = 1.187 ksi

Damper growth in circumferential direction = 0.003669 in

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From literature we know that

Shear force = shear stress*contact area

Damper stiffness K_d = shear force/ deflection

= 4.02E+05 lb/in

So by using shear layer deformation phenomenon damper stiffness is 4.02E+05 lb/in.

Conclusions

In this paper a methodology is developed to design rotating seal- friction damper. Static analysis of 2D and 3D seal is organized to validate the design of friction damper and later a method is proposed to calculate contact stiffness of friction damper. Various authors explained procedure to calculate stiffness of friction damper. Effect of friction coefficient and shear layer deformation is not considered in previous methods. In proposed method above mentioned facts are considered. Therefore using this proposed method accurate stiffness of damper can be obtained.

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